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**SITE SUITABILITY ANALYSIS
FOR AN INTERMOUNTAIN SOLID WASTE FACILITY:**

A STUDY FOR CACHE COUNTY, UTAH

by

Joseph B. Campo

A thesis submitted in partial fulfillment

of the requirements for the degree

of

MASTER OF LANDSCAPE ARCHITECTURE

Approved:

John C. Ellsworth
Major Professor

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Committee Member

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UTAH STATE UNIVERSITY
Logan, Utah
1996

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Joseph B. Campo

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ABSTRACT**Site Suitability Analysis**

For an Intermountain Solid Waste Facility:

A Study for Cache County, Utah

by

Joseph B. Campo, Master of Landscape Architecture

Utah State University, 1996

Major Professor: John C. Ellsworth

Department: Landscape Architecture

Project Directors: Professor Ellsworth

Mr. Roger Sunada, Director of Environmental Health,

City of Logan

The goal of this project was to analyze Cache County for potential sanitary landfill sites covering the period 2020 to 2120. The county population and per capita solid waste were estimated. The minimum landfill size was then calculated.

A geographic information system (GIS) was used for data storage and analysis. Relevant data were gathered. Areas which would not support a landfill

were eliminated. Remaining sites were rated as having slight, moderate, or severe restrictions for use as an area method sanitary landfill based on the Natural Resource Conservation Service (NRCS) Sanitary Facility Report, and the NRCS Soil Interpretations Rating Guide. Seventeen sites were designated as sites for further evaluation.

A landfill ranking system giving a primary and/or secondary rating to data items was developed. Nine prime sites had one secondary rating. These sites should be more closely investigated to determine which are the best potential sites. (136 pages)

CHAPTER I

INTRODUCTION

Statement of the Problem

Cache County is located in northern Utah, 90 miles north of Salt Lake City. Its current population is approximately 70,000, 32,000 of whom live in Logan, the largest city in the county (Montgomery 1993). The only sanitary landfill serving Cache County is located in Logan. The Logan landfill has an estimated life expectancy of 21 more years (Sunada 1994), with an estimated closure date between 2015 and 2020.

Cache County is growing at an annual rate of approximately 2 % (Logan library 1994). It has many natural attractions, friendly people, lots of open space, and a high quality of life. While these factors make Cache County an attractive place to live, growth is starting to have an impact on the county's infrastructure. The County government has been working for several years on a master plan to try to manage this growth. One factor to be considered in the plan is where future generations of Cache County residents will dispose of their solid waste. Because of this growth and the loss of open space, the county is searching for potential sites for a new landfill.

It is estimated it will take between 5 and 15 years to complete site selection and obtain public and design approval for a new landfill (Sunada 1994). It is imperative that the search for a new sanitary landfill begin now, while

potentially suitable sites and land may still be available.

Purpose of This Study

The purpose of this study was to do a land-based analysis of Cache County in order to find potential sites for a future landfill. This study produced a "long list" of potential sites suitable for use as a landfill. In this study, land-use planning methods based on a regional land-planning scale were used. Most data used for this study were also suitable for regional land planning. Potential sites identified at this scale may not turn out to be viable once site-specific field investigations are completed. Given the potential for distortions of data at this scale, the results of this study should be used as a general planning tool only. Specific and thorough on-site investigations of this data are necessary in order to verify the project information.

Future Phases of Study and Other Considerations

The next phase of this siting process, outside the bounds of this study, is to reduce this "long list" to a "short list" of potential sites, composed of two or three of the best sites. These sites would then undergo intensive geologic and physical study to determine the best site the landfill

Early public involvement is essential to this process. Even the best landfill site may not get approved if the public does not support it. Cache County should start to educate the public about this need now by holding public meetings to discuss this project and report its results.

Finally, landfills need not detract from a community's quality of life. While there will certainly be an impact on surrounding communities during the facility's operating life, good management and engineering will minimize this impact. Moreover, a sound design and maintenance plan for closure to reclaim the landfill offers incredible possibilities for open space preservation. Post-closure landfills can support activities such as hiking, wildlife viewing, or even golfing. In the long-term, land values around a closed landfill will increase.

A landscape architect, working in tandem with an engineer, would be an asset throughout the entire siting process, but particularly in the post-closure design phase. This researcher strongly believes that a properly designed, constructed, and managed landfill can be a long-term amenity to Cache County and its citizens.

CHAPTER II

LITERATURE REVIEW

Introduction

This section reviews literature regarding the importance of solid waste management. It will show the necessity for landfills as a part of solid waste management and will address that particular need in Utah. Problems with landfills and success stories will be described. Finally, examples of siting processes will be discussed as well as the role a Geographic Information System (GIS) can play in siting landfills today.

Overview of Solid Waste Management

Solid waste management is increasingly important to modern societies (Hagerty and Pavoni 1974; Lehr 1991; O'Leary and Walsh 1991). To preserve our environment and survive on earth, we must learn to properly manage the solid waste we inevitably create.

There are four generally accepted methods of solid waste management: waste reduction, recycling, incineration, and landfilling (Robinson 1986). These four methods are intertwined. Reduction and recycling, while important, cannot eliminate the need for incinerators and landfills. In the best case scenario, reduction and recycling could reduce landfilled waste by 45% (Lehr 1991). Incinerators, also called waste-to-energy facilities, often meet with public opposition due to the perception of them as air polluters. Investigations of 30

planned incinerator projects in 1983 showed 35% abandoned and 15% in serious difficulty (Robinson 1986). Therefore, landfills are the final waste management option. We dispose of solid waste which cannot be recycled or incinerated in landfills.

The Landfill Component of an Integrated Solid Waste Management Program

Landfills form the backbone of any solid waste management program (NSWMA 1989; Allanach 1992; Poland 1994). Figures show that we landfill between 70 and 85 % of our nation's solid waste (Allanach 1992; Lehr 1991). Landfills will probably always exist in order to handle materials which are simply not manageable any other way. However, literature review reveals a general pessimism about the ability to find new landfill sites.

According to a 1989 special report by the National Solid Wastes Management Association entitled "Public Attitudes Toward Garbage Disposal", 1987 public opinion surveys revealed that while 20 % supported new landfills, 65 % were "adamantly opposed to them" (Smith et al. 1990). Lee and Jones (1991, p. 482) say it has "become virtually impossible to site new municipal solid waste facilities". Public opposition is one of the main reasons for this (Finley and Hogle 1990; Smith et al. 1990). The public, with good reason, has a strong concern about the environmental impacts of landfills.

Landfill space is finite, limited eventually by the available surface of our planet. Of course, available landfill space is actually much smaller. In earlier

times, landfill sites were often chosen without regard to ecological consequences (Walsh 1991). In modern times, growing concern for the planet's environment dictates that every effort must be made to insure that the physical characteristics of a sanitary landfill site meet basic government safety requirements. All landfills are now required by law to meet strict federal Subtitle D regulations, or face closure. Physical siting issues must be properly addressed to insure public safety. Adherence to specified regulations will insure the safest landfill that can be built with modern technology.

Ground water pollution is a key concern. Alternative landfill designs based on negative hydraulic conductivity (Haitjema 1991) and biochemical fermentation (Lee and Jones 1991) have been proposed to try to address this issue, but have not been embraced, perhaps due to skepticism and cost. Further study of these alternatives may be necessary in cases where a highly suitable site is not readily found. Some of the other physical characteristics to be analyzed are geology, hydrology, soils, potential flooding, slope, present land use, and access (Herriman 1972; Loughry 1973; Hagerty and Pavoni 1974; Hendrickson and Romano 1980; Lane and McDonald 1983; Star 1989; Smith et al. 1990; O'Leary and Walsh, 1991).

New landfill sites must be chosen carefully, paying strict attention to legal ramifications, the public's environmental concerns, and their general opposition to landfills being located in or near their community. Landfills which are properly

sited, designed, and operated can be an acceptable land use both ecologically and economically, as well as socially.

Background: The Landfill Siting Problem

It is difficult to find sites for new landfills and even harder to actually bring them into service (Lee and Jones 1991; Lane and McDonald 1983). Landfills are something our society needs but no one wants to accommodate. The NIMBY ("not in my backyard") attitude is prevalent. How will Utah handle this issue?

The Resource Conservation and Recovery Act of 1976 (RCRA) set federal standards for resource recovery, hazardous waste, and solid waste management. Its goal was to create market conditions to promote environmental protection by requiring those who benefit "from the functions that create the waste to pay the cost of its disposal" (Robinson 1986, p. 10). In a 1993 report, it was estimated that more than 60 % of Utah landfills (100 out of 164) would close due to stricter RCRA based Subtitle D landfill regulations implemented in October 1993 (Repa 1993). According to a 1996 update report by the National Solid Waste Management Association, Utah now has 63 landfills in service (Repa and Blakey 1996).

Landfill Problems and Success Stories

Landfills in service can have a negative impact on surrounding communities. Odor problems and groundwater pollution are two major issues.

Odor problems caused the shutdown of three mixed waste composter facilities in 1991 and 1992 (Segall and Redd 1994). A National Solid Wastes Management Association survey (NSWMA 1989) shows that between 1981 and 1988, the percent of people who felt groundwater pollution was a serious problem rose from 28 % to 54 %.

Research reveals however, that long-range planning and sound design can turn landfills into amenities for nearby local communities. At the Fresh Kills landfill on Staten Island, New York, the New York City Department of Sanitation, with a landscape architect as the project director, successfully completed a five year restoration demonstration project. An oak-scrubforest and grass/shrubland were restored on a closed section of the landfill and early successional stages of revegetation were established. This helped to preserve the local gene pool and add to the ecological biodiversity of the area (Young 1993; Young 1994).

In San Diego, the Miramar landfill is an excellent example of environmental management. Restoration of the disturbed area has brought back wildlife and native plants. Controlled burns were used to aid revegetation. Wetlands make the facility appear like a nature preserve (Meade 1992). In Lawrence, Kansas, a 210 acre landfill was turned into a wildlife and recreation area, with much of the work being done by students during the summer (Watkins 1985).

At the Acmar landfill near Birmingham, Alabama, managers inform the

oversight committee of all landfill happenings, both good and bad. They support the local community through charitable food donations, scholarships, and books donated to the local Head Start Program (Thompson 1993). This professional attitude and community involvement has made this landfill a success.

In Belleville, Michigan, the local landfill is a community resource center. Landfill methane gas is providing enough electric power for 1,800 homes. An on-site hydroponic greenhouse grows vegetables which are sold to distributors who sell retail produce to some of the finest restaurants in the mid-west (Logsdon 1989). Near Riverview, Michigan, their landfill was turned into a ski hill. Surrounding property values have increased. Methane gas from the landfill produces enough electricity for 10,000 homes on a continuing basis. The area serves as a recreational park and an active landfill at the same time, a true community resource (Logsdon 1989).

In Lake County, Illinois, the Countryside Landfill demonstrates the value of teamwork between government, landfill owners, and landscape architects.

Under previous owners, the landfill had twice been denied expansion permits. The new owners, USA Waste Service, Inc., contacted the landscape architecture firm Peter Walker William Johnson and Partners (PWWJ) for assistance. PWWJ developed a plan, working with all concerned parties, to blend the landfill in with the surrounding areas and allow it to function as an open space connector between two nearby greenways. The plan was accepted by all parties as well as

the local community and expansion permits were granted in 1994 (Johnson 1996).

More non-conventional proposals have come from the 606 Studio at California State Polytechnic University in Pomona. This studio is taught by Professor John Lyle, a well known landscape architect and architect. One of Professor Lyle's projects is called the Institute for Regenerative Studies, located at the Spadra landfill of the Los Angeles Sanitation District. By recycling and self sufficient living off the land, Lyle aims to show how Los Angeles County could eliminate the need for landfills (Thompson 1991).

Landfill Siting Analysis Systems

Research reveals that computer-assisted analysis for use in siting landfills has been going on since the 1970s. All of these analyses involve computer mapping of factors considered in siting a landfill, such as geology, hydrology, or topography. One analysis system used computer-linked terrain analysis to total points given to rating criteria in a study for Roscommon County, Michigan (Tilman et al. 1975). Other analyses in the mid 1970s used computer mapping as well (Dunn and Marshall 1974; Ohio Department of Natural Resources 1974).

In the 1980s, one analysis system used capability analysis combined with computer graphics in siting landfills for Oconto County, Wisconsin. IMGRID, a state-of-the-art computer graphics program, was used to map the results (Johnston and Stieglitz 1984). Another analysis system did a capability analysis

of Fairfax, Virginia, based on geologic thickness, geologic type, topography, and linear sub-surface geologic features (Van-Driel 1982). Other studies show similar capability analysis processes (KCPC 1977; Lane and McDonald 1983).

In the 1990s, with the advancement of computer analysis, Geographic Information Systems (GIS) have become the most popular tool used by government agencies and businesses for land-use analysis. GIS will make land-use analyses faster and more flexible, but will probably not make successfully siting a new landfill any easier (Michaels 1988). GIS offers the opportunity to model a landfill's progress over time using satellite images (Ruth et al. 1980; Johnson et al. 1993). GIS can also be used to measure movement of pollutants through soil (Eddy and Looney 1993), though the accuracy of these models is open to question. Still, GIS is a high powered land-use analysis tool ideal for this landfill site suitability analysis.

CHAPTER III

METHODOLOGY

Introduction

In order to produce a list of potentially suitable sites for a future landfill in Cache County, an eleven step process was developed. The details of how each step was completed are explained following this list.

Step 1. The population of Cache County for the time period being studied was estimated extrapolating from existing population and projections.

Step 2. The amount of solid waste generated per person per day was estimated using existing solid waste figures from 1994 for Logan landfill.

Step 3. The area required for the landfill was calculated based on information obtained from Steps 1 and 2, using a formula provided by Mr. Hamud.

Step 4. A table of desired landfill siting data for the analysis phases was developed and information about Utah state regulations and U.S. federal government regulations regarding landfill siting requirements was gathered based on the table of desired data.

Step 5. The desired data was gathered and a GIS database was constructed. A strategy was developed for building the database and completing the data analysis. This strategy was to gather available county-wide data on elements which would preclude development of a landfill on any site containing that element. This strategy will be explained in depth in Step 6.

Step 6. Unsuitable areas were eliminated and potential landfill sites were identified. In order to complete this step, eleven GIS coverages of individual data items were created. A coverage is a digital map stored in the GIS database. These eleven individual coverages were then combined into one coverage containing data from all the individual coverages. Based on the required area from Step 3, the Utah state regulations and U.S. federal regulations from Step 5 above, and input from experts about desired parameters for certain data (e.g., buffer zone around waterbodies), unsuitable areas were eliminated and maps were produced showing the remaining areas which were still considered potential sites for a future landfill.

Step 7. The potential landfill site maps produced in Step 6 were evaluated and the direction to be followed for the remaining parts of the study was decided upon. The researcher was directed to evaluate all potential 25 year landfill sites.

Step 8. Required future data needs to complete evaluation of all potential 25 year landfill sites were determined. A desired data list was developed from the data list created in Step 4 considering the eleven data items eliminated in Step 6.

Step 9. These additional desired data were gathered and prepared for analysis and evaluation.

Step 10. The information gathered in Step 9 was used to analyze and evaluate the potential 25 year sites and a list of sites with slight, moderate, and severe restrictions for suitability as an area method landfill were produced.

Step 11. The results from Step 10 were examined and a "long list" of potential sites for further analysis was produced.

Step 1 - Population Estimate

The first step taken was to estimate the population of Cache County for the 100 year life span of the new solid waste facility (years 2020 to 2120). It is extremely difficult to forecast populations for a 100 year time frame. In this study, the time frame is even longer, involving 100 year estimates starting from when the present solid waste facility is expected to reach capacity, around the year 2020. Most forecasts do not go beyond 20 or 30 years since there are many factors which can influence population growth, and these factors change with time. A multitude of methods exist to forecast population growth, with a wide range of success (Pittinger 1976; Raymondo 1992). For this reason, the Governor's Office of Planning and Budget (OPB) for the State of Utah was contacted for assistance since population forecasting is their expertise.

The OPB suggested that simple extrapolation of a base annual

population growth rate be used since the 100 year time period is going to be an educated guess at best. The researcher therefore decided to use the extrapolation method to forecast the future population of Cache County. Published data forecasts for Cache County's population exist through the year 2020. This was used as a starting point to forecast the population through the year 2120.

The OPB suggested that three comparisons be made using different annual growth rates. An exponential formula was run in order to derive annual growth rates. The formula was as follows:

$$(\text{ending population} / \text{beginning population})^{(1 / \# \text{ of years covered}) - 1}$$

For example, in case number one, the formula applied was

$(116636 / 70183)^{(1/30)-1}$. The figure 116,636 is the ending population forecasted for 2020. The figure 70,183 is the beginning population for 1990, and 30 is the number of years covered for this period.

In case number one, an annual growth rate of 1.71 % was used and extrapolated out to the year 2120. The 1.71% rate, calculated using the formula above, was the average for the years 1990 to 2020 which was projected in more detailed population projections done by the OPB. This resulted in an estimated population of 635,621 by the year 2120.

In case number two, an annual growth rate of 1.49 % was used and extrapolated out to the year 2120. The 1.49 % annual growth rate was based on

the average annual growth rate for the years 2010 to 2020 projected by the OPB. This resulted in an estimated population of 511,868 by the year 2120.

In case number three, an annual growth rate of 1.00 % was used and extrapolated out to the year 2120. The OPB had no solid basis for using this 1 % annual growth rate other than that it was well below the current Utah state-wide growth rate which exceeds 2 % and also below the estimated annual growth rates for Cache County predicted through 2020. It gave the researcher an idea of what the population figures would be like if a sharp decline in the annual growth rate occurred. This resulted in an estimated population of 315,479 by the year 2020. These results are displayed in Figure 1.

Cache County Population Forecast From 1990 to 2120 (Extrapolating from population forecast for 2020)										
	1990	2000	2010	2020	2030	2040	2060	2080	2100	2120
Annual Growth Rate										
1.71%	70183	83440	100527	116636	138187.6	163721.5	229815.2	322590.7	452819.3	635621
1.49%	70183	83440	100527	116636	135227.5	156782.5	210747.6	283287.7	380796.4	511868
1.0%	70183	83440	100527	116636	128838.7	142318.1	173655.1	211892.2	258548.8	315479
Note: above figures do not include Utah State University students										
Utah State University Student Population Forecast from 1990 to 2120										
	13000	23000	25000	25000	25000	25000	25000	25000	25000	25000

Figure 1. Cache County Population Forecast from 1990 to 2120.

The Bear River Association of Governments (BRAG) and the Cache County Planning Commission were contacted to check if there were any maximum population limits which existed based on previous studies of build-out scenarios for the county. There are presently no such maximum population scenarios or limits.

The researcher decided to use the annual growth rate of 1.49 % for several reasons. The 1.71% annual growth rate generates a population figure which is extremely high for an area which is used to single family housing and open space. Moreover, if this scenario were assumed, such a build-out might require expansion into all available open land, leaving little land for a solid waste facility. The 1.00 % rate yields a figure which is approximately four times the present population. This is perhaps too low a figure. From 1890 to 1990 the population of Cache County increased from 15,509 to 70,183, an increase of approximately 450 % (State of Utah 1994a). The annual growth rate of 1.49 % was assumed since it represents a high middle ground. The forecasted population for Cache County for the year 2120 is assumed to be 511,868. For the purposes of this study, it is better to overestimate the population rather than underestimate it.

During this population research, the issue of Utah State University (USU)

- students came up. As per the OPB, it was believed that USU students were counted in the Logan city population. The decennial census is taken on April

first. On April first, the majority of USU students still live in Cache County. According to the OPB, normal census data indicates the place of residence as the town where you live for more than six months of the year. Since most students live in Cache County for at least eight months of the year, their permanent place of residence would be Cache County and they would be counted as county residents. However, Mr. Mark Teuscher of Cache County Economic Development Board said his information is that USU students are not included in county population estimates and were definitely not counted in the 1990 decennial census. This became an area of confusion in forecasting the population.

The researcher decided to try to estimate the USU student population and solid waste they generate and include these estimates in this study. Mr. Teuscher has studied this issue and found that by the year 2002, the number of full-time students enrolled at USU should top out at 25,000 based on pure size limitations. Since this study estimates solid waste generated after the year 2020, the student population was assumed to be 25,000 per year for the entire study period. The solid waste generated per student per day will be discussed in the following section covering solid waste estimates.

Step 2 - Solid Waste Estimate

- The solid waste generated in Cache County comes from four different waste generator categories: residents, non-residents, industries, and special

waste. However, after discussing this with Mr. Hamud, Engineer for the City of Logan, the researcher decided to estimate the solid waste generated for the county on a pure "pounds per person per day" basis, using the Cache County population forecast. The rationale for this was that residents who go to work at an industry are already counted as waste generators at their residence. The waste generated at their place of work is assumed to count as part of their per person per day solid waste amount generated.

The average amount of solid waste generated per person per day was based on the 1994 Cache County figures which are fairly accurate, according to Mr. Hamud. The average pounds of solid waste generated per person per day were calculated based on the amount of solid waste disposed of in Logan landfill for 1994 and the estimated population of Cache County in 1994.

For the year of 1994, 60,781 tons of solid waste was disposed of in Logan landfill, an average of 200 tons per day (SWEHD 1994). The population of Cache County in 1994 was estimated to be 77,096 (State of Utah 1994b). The amount of solid waste generated per person per day for 1994 was calculated by dividing the total solid waste disposed in Logan landfill during 1994 by the population of Cache County, converting it to pounds per year, and dividing by 365 days to obtain an average amount of pounds per person per day.

For 1994, the average solid waste landfilled was 4.3 pounds per person per day as shown on the following page.

$60,781 \text{ tons per year} / 77,096 \text{ persons} = .788 \text{ tons per person per year}$

$.788 \text{ tons per person per year} \times 2,000 \text{ lbs / ton} = 1576 \text{ lbs per person per year}$

$1576 \text{ lbs per person per year} / 365 \text{ days/year} = 4.3 \text{ lbs per person per day}$

The Environmental Protection Agency (EPA) states that the national average of solid waste generated is 4.4 pounds per person per day before recycling and recovery. After recycling and recovery, 3.4 pounds per person per day were disposed of in landfills. The EPA projects that the average waste generation rate will drop to 4.3 pounds per person per day by the year 2000 (US EPA 1994b).

Cache County has a higher per capita waste generation rate than the national average. This is due to the fact that this forecast took the entire amount of solid waste disposed and divided it by the total population, without allowing for non-resident, industrial, and special waste. This is also possibly due to plentiful landfill space and lower recycling rates than the national average of approximately 22 % of per capita solid waste (US EPA 1994b). Cache County Environmental Health Department reports that approximately 11 % of solid waste generated in 1994 in Cache County was recycled (SWEHD 1994).

Furthermore, the EPA estimates that by the year 2000, the national average reduction of solid waste through recycling, recovery, and composting of materials will increase to 30 % (US EPA 1994b).

For the purposes of this study, a per capita waste generation rate of 4.8 pounds per person per day was assumed as a constant for the 100 year study period. There are several reasons for this assumption. First, the figure of 4.3 pounds per person per day cited by the EPA is a national average. States will have varying per capita waste generation rates. Second, the researcher believes that the average Utahn does not have the recycling ethic that people have who come from crowded areas where landfill space is sparse or non-existent. This is based on the researchers experience of having lived over 20 years in the northeast U.S., in New York City and Boston, and from comments heard from new Cache County residents who came here from California. These reasons convinced the researcher to use the higher rate of 4.8 pounds per person per day.

Additionally, a 20 % waste reduction level was assumed as a constant for the same 100 year study period. While it is impossible to predict solid waste flows with certainty for such a long time frame, it seems plausible that Cache County will be able to more than double its recovery rate of solid waste materials in a 100 year period, especially since the EPA predicts a national average waste recovery rate of 30 % in 5 years. Pressure will be brought upon the county to increase recycling efforts as the population grows and the amount of landfill space shrinks. Therefore, this 20 % reduction was applied in the calculation starting as of the year 2020.

The solid waste generated per student per day was based on the 1994 figures for billings to USU Physical Plant which disposes of solid waste from USU at the present landfill. The researcher realizes that not only students produce waste, but faculty and employees as well. However, he decided to use only the student population in the USU waste generation calculation. USU was billed for a total of \$42,219.00 for 1994 disposal. They are charged \$16.00 per ton. Dividing total billing by charge per ton came to 2,639 tons or 5,278,000 pounds of solid waste generated by USU students in 1994. Dividing this by 365 days came out to 14,500 pounds of solid waste per day. Using an estimated 17,000 students for 1994, this came out to approximately 0.85 pounds per student per day. This figure seems to be a little low based on the researcher's experience as a student. One explanation is that not all 17,000 students live on-campus. This would bring down the per capita waste rate considerably. For the purpose of this study however, the researcher decided to use the number of estimated full-time students as the total number of student waste generators. The rate was set at 1.0 pounds per student per day which is approximately a 20 % increase over the actual 1994 figures. This solid waste per student rate was set higher because it allows for possible underestimates in the calculation of this rate as well as the lack of recycling ethic from international students who may be coming from areas where recycling efforts are not as advanced as areas of the United States. Since USU has its own recycling plant, there was no reduction applied for waste

recycling or recovery. This will give some idea of the impact of the student population on the solid waste disposed of in the landfill.

It is not the intent of this study to try to exactly predict either the population or solid waste generated in Cache County for the 100 year study period. Rather, these figures are necessary in order to determine the size requirements of the main target of this study, namely a new solid waste facility. With this in mind, the population, solid waste generation, and recycling figures used in this study may represent a worst-case scenario. Therefore, the size of the solid waste facility would represent a maximum figure and its life span would probably exceed those estimated by this study if these figures improve from their worst-case scenario levels.

Step 3 - Calculate Areal Requirement for the Landfill

The areal requirement for the solid waste facility was calculated based on the population and solid waste estimates from Steps 1 and 2 above. The annual population growth rate of 1.49 % was used as well as solid waste generation figures of 4.8 pounds per person per day and 1.0 pounds per student per day. The following formula was applied to estimate the required landfill area (Tchobanoglous et al. 1993):

1. Determine the solid waste generation rate in tons per day

$$\begin{aligned} \text{Rate} &= \frac{(\text{population}) \times (4.8 \text{ lbs / per person per day})}{2000 \text{ lbs / ton}} \\ &= \text{tons per day} \end{aligned}$$

2. Determine the volume required per day

$$\text{Volume} = (\text{tons per day}) \times (2000 \text{ lbs / ton})$$

$$850 \text{ lbs / cu yd.} \quad // \text{ in-place waste density} //$$

$$= \text{cu yds / day}$$

3. Determine the volume of soil cover material required per day

a. assume daily cell depth of 10 ft

b. area covered per day = (cu yds per day of waste) / (depth)

c. daily cover volume = (area covered per day) X (.5 ft)

note: assume 6 inches of soil as daily cover

d. assume the number of working days per year as 303 (SWFAR 1994)

e. volume of daily soil cover per year = (daily cover volume) X 303

4. Determine the area required

$$\text{Area} = (\text{cu yds / day}) \times (365 \text{ days / year}) \times (27 \text{ cu ft / cu yd})$$

$$(\text{average depth of compacted waste}) \times (43560 \text{ sq ft / acre})$$

$$= \text{acres required / year}$$

In the above formulas the population varies depending on the year, therefore the rate and volume calculations will vary as well. The in-place waste density (#2 above) is an estimate of the compacted specific weight of the waste per cubic yard (SWEHD 1994). The average depth of the compacted waste for this study (#4 above) was assumed to be 40 feet. This is the depth of the solid waste from the base of the waste to the top of the waste. According to Mr. Hamud, City of Logan Engineer, this can represent different development scenarios. For example, it can represent a 10 foot depth below ground and 30 foot elevation above ground. He suggested using an average of approximately 40 feet for the purposes of this study. This can be an important variable in all future capacity studies for a new solid waste facility.

It is worth noting that the inclusion of the USU student population in the study resulted in an additional disposal capacity requirement of less than 25 acres for the 100 year period. Should the estimates be low, the additional size required to compensate for student generated waste would not require large land additions.

Based on these data, a 100 year solid waste facility from the years 2020 to 2120 will require 895.3 acres of land. Additionally, areal requirements for a solid waste facility were calculated for 25 year periods beginning at the year 2020. This provides the minimum size required for smaller sites with 25 years of disposal capacity in case a site with 100 years of disposal capacity is not found. See Figure 2 for details.



Figure 2 Estimated Required Acreage for Solid Waste Facility 2020-2120

Estimated Required Acreage For Solid Waste Facility From 2020 to 2120 (Extrapolating from population forecast for 2020)						
Year	2020	2045	2070	2095	2120	
Population (1.49% annual growth)	116636	168816.1	244340.4	353652.4	511867.9	
Solid waste generated (Pounds per person per day)	4.8	4.8	4.8	4.8	4.8	
Utah State University students	25000	25000	25000	25000	25000	
Solid waste generated (Pounds per student per day)	1	1	1	1	1	
Total solid waste generated (Tons per day) assuming 20% reduction due recycling & recovery	236.4	336.6	481.6	691.5	995.3	
Volume required per day (Cubic yards per day)	585.6	833.8	1192.9	1712.7	2465.1	
Soil cover volume required (Cubic yards per working day)	29.3	41.7	59.6	85.6	123.3	
Acres required per year (not including ancillary services)	3.3	4.7	6.8	9.7	14.0	
Required acreage for landfilled waste (not including ancillary services)		103.4	246.4	451.4	746.0	
Required acreage for ancillary services (required waste acreage * 20 %)		20.7	49.3	90.3	149.2	
Cumulative Total acreage required for one solid waste facility with 100 years disposal capacity		124.1	295.7	541.6	895.3	
Required Acreage If Facility Located at Four Separate Facilities						
Required acreage for (not including ancillary services)	Time period	2020-204	2046-207	2071-209	2096-2120	
		103.4	143.0	205.0	294.7	
Required acreage for ancillary services (required waste acreage * 20 %)		20.7	28.6	41.0	58.9	
Total acreage required for separate solid waste facilities with 25 years disposal capacity per facility		124.1	171.6	245.9	353.6	Cumulative Total
						895.3

Figure 2. Estimated Required Acreage for Solid Waste Facility from 2020-2120.

Step 4 - Develop a Table of Desired Data and Regulations

All new solid waste facilities are required to meet federal and state regulations regarding location standards. A complete list of applicable Utah state regulations is attached in Appendix A. The list of desired data was compiled based on literature research and specifically a list of desired data provided by Mr. Hamud.

A table was compiled showing the desired data and any regulations regarding this data (see Appendix B). This table establishes some minimum parameters for the data desired for this study. It is interesting to note that while a good part of the state regulations were duplications of the federal regulations, many of them were specific (i.e., water, general location) where the federal regulation was not. This table was first used to establish a list of desired criteria within each desired data group. For example, from 1. Groundwater, the desired criteria includes location of aquifers, drinking water source protection area, wells, and springs. Once these desired criteria were gleaned from Appendix B, possible resource contacts were developed from which these data could be gathered.

Step 5 - Data Gathering Process and Database Construction

An effort was made to obtain all the desired data as specified in Appendix B. The following is a description of the process carried out in obtaining these data, pertinent information gathered from the data provider, and

the actual data gathered for database construction. Specific information about entering all these data in GIS will be provided in Step 6.

The scale and accuracy of the data used is an important issue because it directly affects the accuracy of the results. The pixel size used in my GIS database and in production of all the maps is 30 meters square. The scales used varied from 1:20,000 for soils maps, to 1:126,720 for the National Parks and Forests map. No ratio scale was available for floodplains and zoning, but the researcher believes their scale is even larger than this. Therefore, this has an impact on the accuracy of these data. Since this is a regional study, the results are to be used for general planning purposes only. Site-specific field investigations are necessary to verify the information from this study. Some basic scale and accuracy information from this step are summarized in Figure 3. For more detailed information, please read Step 5 below.

1. Groundwater

The source used for general location of groundwater aquifers was obtained from the Utah Department of Environmental Quality, Division of Water Quality (Anderson et al. 1994). The map titled "Recharge and Discharge Areas" shows primary recharge areas, secondary recharge areas, and discharge areas. This map was produced by the U.S. Geological Survey (USGS) and was based on USGS digital data at a scale 1:100,000 from 1978, 1979, and 1984. The Universal Transverse Mercator projection method was used.

<u>Data item</u>	<u>Data Source</u>	<u>Data Scale</u>	<u>Data Pixel Size</u>
1. Groundwater	USGS	1:100,000	n/a
2. Well water	Utah Division of Water Resources	n/a	n/a
3. Water table	Cache soil survey	1:20,000	n/a
4. Surface water	USU Dept. Of Geography	1:100,000	30 meters
5. Soils	Cache soil survey	1:20,000	n/a
6. Slope	Cache soil survey	1:20,000	n/a
7. Depth to bedrock	Cache soil survey	1:20,000	n/a
8. Sub-surface geology	USU Dept. Of Geology	½ inch = 1 mile	n/a
9. Zoning and planning	Cache County Corporation	1 section = 1 mile	n/a
10. Built-up areas	USU Dept. Of Geography	unknown	30 meters
11. Farmland	NRCS	1:100,000	n/a
12. National parks and forests	U.S. Forest Service	1:126,720	n/a
13. Environmentally sensitive areas	Utah Gap analysis	unknown	100 meters
14. Historic structures	Data gathered indicates historic structures exists in built-up areas only. Consult the State Historical Society when doing site-specific investigations to verify this information.		
15. Significant archeological sites	Consultations indicate there are no significant archeological sites in Cache Valley. Contact the State History Office to have them perform site-specific field surveys once the number of sites is narrowed down.		
16. Unstable areas	USU Dept. Of Civil and Environmental Engineering	1:48,000	n/a

Figure 3. Summary of Desired Data List Items: Source, Scale, and Pixel Size.

<u>Data item</u>	<u>Data Source</u>	<u>Data Scale</u>	<u>Data Pixel Size</u>
17. Fault zones	USU Dept. Of Geography	unknown	30 meters
18. Airports	USU Dept. Of Geography	unknown	30 meters
19. Floodplains	Cache County Corporation	1 section = 1 mile	n/a
20. Seismic impact zones	USU Dept. Of Civil and Environmental Engineering	All of northern Utah is located in a seismic impact zone, based on its definition. Assume that sufficient construction techniques will provide required structural stability	
21. Climate	USU Dept. Of Biometeorology	n/a	n/a
22. Visual Impact Zones	USU Dept. Of Landscape Architecture	n/a	n/a
23. Roads and Access/ Travel times	USU Dept. Of Geography	unknown	30 meters

Note: n/a = not applicable

Figure 3. Contd. Summary of Desired Data List Items: Source, Scale, and Pixel.

As per discussions with Mr. Atkins with the Utah Division of Water Resources in Logan, the most appropriate area for location of a sanitary landfill would be a discharge area. This is due to the upward vertical movement of the water which decreases the possibility of groundwater contamination.

2. Well Water

As per discussions with Mr. Atkins with the Utah Division of Water Resources in Logan, there are over 5,000 wells located within Cache County. The researcher therefore decided to gather site specific information on wellhead location once unsuitable areas were eliminated.

3. Water table

The researcher was unable to find a suitable water table map covering the entire county. Potentiometric maps were found but these contain only the level of groundwater as feet above sea level, and not depth to groundwater. To obtain this information would require overlaying a topographic map on top of the potentiometric map. This would require more computer storage space and research time than was available. The researcher therefore decided to use data provided in the 1974 Cache County Soil Survey limited to the potential sites delineated in Step 6.

4. Surface Water

Two digital GIS coverages (maps) of Cache County surface water systems were obtained through Utah State University Department of Geography. These coverages were copied from Utah Gap analysis CDs included in the Utah Gap Analysis information package (Edwards et al. 1995). One coverage delineated watercourses and the other coverage delineated waterbodies. The Gap data scale was 1:100,000 using 30 meter pixels.

5. Soils

The researcher was unable to find a suitable soils map covering the entire county. He therefore decided to use data provided in the 1974 Cache County Soil Survey limited to the potential sites delineated in Step 6.

6. Slope

The researcher was unable to find a suitable slope map covering the entire county. He therefore decided to use data provided in the 1974 Cache County Soil Survey limited to the potential sites delineated in Step 6.

One source of slope data considered was the 1995 Sensitive Area Map produced by Cache County Corporation. This map delineates steep slopes as slopes exceeding 10 % grades. These areas are considered sensitive areas. The researcher discussed this map with Cache County Planner Mr. Teuscher, who pointed out that the county would probably refuse a permit for a landfill in these steep slope areas mostly on the grounds of visual impact. It may make sense to eliminate these areas since the chances they would receive the permit are low. However, the accuracy of these delineated 10 % slope areas was uncertain based on the researcher's working knowledge of Cache County topography. The researcher therefore decided to use the slopes provided in the 1974 Cache County Soil Survey.

7. Depth to Bedrock

The researcher was unable to find a suitable depth to bedrock map covering the entire county and therefore decided to use data provided in the 1974 Cache County Soil Survey limited to the potential sites delineated in Step 6.

8. Sub-surface Geology

A county-wide sub-surface geology map was obtained from the Utah Geological Survey office in Salt Lake City. It was produced in 1948 by J. Stewart Williams who was previously Head of the Geology Department at Utah State University. It is titled "Geologic Atlas of Utah, Cache County". The researcher decided not to use this map to eliminate unsuitable areas but rather to include the sub-surface geologic data as part of the information for each potential site delineated in Step 6. The map scale is 1/2 inch = 1 mile.

9. Zoning and Planning

The zoning information was gathered from the 1995 Zoning Map produced by Cache County Corporation. The scale was 1 section equals 1 mile. No ratio scale was available. Seven zoning types are shown on this map: agricultural, cities and towns, commercial, forest-recreation, manufacturing, planned unit development, and residential. The three dominant zones on this map are forest-recreation, agriculture, and cities and towns. The largest area is forest-recreation because of the location of Cache National Forest. Since a landfill would be difficult to site in this area, this zone will not be considered as a potential site for this study. The next largest area is agriculture. Per Cache County ordinance #90-15, Chapter 4, Agricultural zone (A), a sanitary landfill is a permitted conditional use in this zone. The next largest zone, cities and towns, does not permit a sanitary landfill as a use. Therefore, the only potential site

locations are in the agriculture zone.

10. Built up Areas

A digital GIS coverage of Cache County land uses was obtained through Utah State University Department of Geography. One of the land uses delineated on this coverage was built-up areas. These built-up areas were extracted from this coverage and put onto an individual built-up area coverage.

11. Farmland

The map of important farmlands was obtained from the Logan division of the Natural Resource Conservation Service (NRCS). This map was compiled by the USGS in 1976 from 1:24,000 scale topographic maps dated 1955-1969. It was partially revised in 1976 but the revised information was not field checked. It uses the Universal Transverse Mercator projection system and complies with national map accuracy standards. The scale is 1:100,000. This map delineates prime farmland, farmland of statewide importance (irrigated), farmland of statewide importance (non-irrigated), additional farmland of local importance, as well as general location of water and urban areas. This map was used as a base map for developing many of the GIS coverages used in this study.

12. National Parks and National Forests

The national parks and national forest information was gathered from the U.S. Forest Service, Logan District. The map used is titled "Wasatch-Cache National Forest, Ogden and Logan Ranger districts". This map provided exact

information on the boundary lines of national forest land in Cache County. It also provided information on location of wilderness areas as well as state recreation areas. This map was constructed in 1993 by the USDA Forest Service Geometronics Service Center, Salt Lake City, Utah from Primary Base Series and USGS quadrangle maps. The land status shown is valid as of 1992. The map scale is 1:126,720.

13. Environmentally Sensitive Areas

Environmentally sensitive areas are described as areas which are ecologically and scientifically significant. For the purpose of this study, this was determined to include wetlands, lowland riparian areas, wet meadows, and wildlife management areas. A digital GIS coverage of Cache County vegetation types was obtained through Utah State University Department of Geography. This coverage was copied from Utah Gap analysis CDs included in the Utah Gap Analysis information package (Edwards et al. 1995). The Gap data level of accuracy was 100 meter pixels. See Step 6 for more details on this process. The information on location of Wildlife Management Areas was obtained from the same map which indicated the national forest boundary, data item Number 12 above.

14. Historic Structures

Information regarding location of historic structures listed on the National and State Registry of Historic Sites was obtained from The State Historical

Society, State Preservation specialist, located in Salt Lake City. All historic sites seem to be located within cities which are already included as built-up areas, and would therefore receive proper protection. The researcher suggests that once more specific sites are delineated in future phases of this siting process which are outside the frame of this study, it would be worthwhile to consult the State Historical Society again in order to verify this information.

15. Significant Archeological Sites

The State History Office, State Archeological Assistant, in Salt Lake City was contacted in reference to location of possible significant archeological sites in Cache Valley. The Assistant said that he was not immediately aware of any, but that he would have to perform a survey on the delineated areas to confirm this. Once areas are narrowed down to township and range locations, he would perform the survey for gas and travel expenses to Logan. Due to the time constraint for estimated completion of this project, it will be assumed that there are no significant archeological sites which preclude siting a landfill in Cache County. The researcher strongly suggests that the State History Office be contacted after sites are narrowed down for verification of this assumption.

16. Unstable Areas

The researcher was unable to find a suitable map which would delineate unstable areas since this is a very general term. For the purpose of this study, he decided to use a county liquefaction potential map developed by the Utah

State University Civil Engineering Department. The scale of this map was 1:48,000. This map delineates the potential for earth to liquefy in case of an earthquake in Cache County. The researcher decided not to use this map to eliminate unsuitable areas but rather to include the liquefaction potential data as part of the information for each potential site delineated in Step 6.

17. Fault Zones

A digital GIS coverage of Cache County faults was obtained through Utah State University Department of Geography. This coverage was used to delineate fault lines in Cache County.

18. Airports

Airport data were extracted from the built-up area digital GIS coverage obtained through Utah State University Department of Geography. Location of a landfill site in reference to the airport was taken as a factor to be considered, but not necessarily one which would make a potential site unsuitable. The researcher therefore decided to not use this map to eliminate unsuitable areas but rather to include the distance to airport data as part of the information for each potential site delineated in Step 6.

19. Floodplains

The floodplains information was gathered from the 1995 Sensitive Area Map produced by Cache County Corporation. This map was originally developed from information provided by the Federal Emergency Management

Agency (FEMA).

20. Seismic Impact Zones

The researcher discussed this data item with Dr. Anderson at Utah State University, Civil Engineering Department. With Dr. Anderson's assistance and based on the definition of "seismic impact zone", it was discovered that all of northern Utah is located in a seismic impact zone. The researcher therefore assumed that sufficient engineering techniques will be used in construction of any new potential landfill to provide required structural stability based on state and federal regulations. A seismic impact zone is described as an area with a ten % or greater probability that the maximum horizontal acceleration in lithified earth material, expressed as a percentage of the earth's gravitational pull (g), will exceed .10g in 250 years (OFR 1995).

21. Climate

The only climatic factors which were considered in this study were wind velocity and wind direction. Utah State University, Department of Biometeorology, provided 1994 quarterly and annual wind roses from two wind monitoring stations located in Cache County. The researcher decided to not use this map to eliminate unsuitable areas but rather to include wind data as part of the information for each potential site delineated in Step 6.

22. Visual Impact Zones

There are no specific regulations regarding visual impact requirements

when siting a landfill. Therefore, this study considered potential sites' impact on visual quality based on proximity to key main roads. This necessitated a subjective rating for this criterion.

23. Roads and Access / Travel Times

A digital GIS coverage of Cache County roads was obtained through Utah State University Department of Geography. These coverages were copied from an existing database onto the database being developed for this study. Potential sites had information about approximate distance to the sites from Logan, considered the centroid for waste generation for Cache County.

Step 6 - Eliminate Unsuitable Areas and Delineate Potential Landfill Sites

Before explaining the process used in Step 6, it will be helpful to provide some general GIS system information and explanations of certain terms used.

Hardware: *SUN Sparcstation computers*

Operating Software: *Solaris based system using ESRI ARC/INFO software. This includes ARC, INFO, ARCEDIT, ARCPLOT, and ARCVIEW.*

Digitizer: *Calcomp 9500 digitizer*

RMS: *Root mean square (a measure of accuracy in registering maps to be digitized)*

PAT: *Polygon attribute table (storage for attribute information)*

In Step 6, unsuitable areas were eliminated and potential landfill sites were delineated. In order to complete this step, 11 GIS coverages of individual

data items were created. The 11 data items which were used to preclude siting of a landfill were as follows: water recharge areas (groundwater), watercourses, waterbodies, zoning, built-up areas, farmland, wilderness and wildlife management areas, national forest boundary lines, wetlands, fault zones, and floodplains.

The GIS software used in this step consists of ARC, ARCEDIT, INFO and ARCVIEW. ARC handles topology (geographic reference) of features such as arcs, points, and lines. ARCEDIT allows editing of ARC files. INFO stores information about feature descriptions and how the features are related to each other. The main INFO table which will be referred to in this step is the PAT. This PAT stores all relevant information about polygons contained in a coverage. ARCVIEW was used to produce the graphic images in this report.

The strategy used to delineate potential landfill sites was to insert an item called 'ng', meaning 'no-go', in each coverage's PAT. No-go items mean that it will be unsuitable to site a landfill in that area. For example, in water recharge areas, it is unsuitable to site a landfill in either primary or secondary recharge zones. These zones are therefore considered no-go areas. Any no-go area was assigned a value of 10. Any area outside of the no-go areas was assigned a value of 0. An area with a value of 0 is still considered a potential landfill site based on that particular data item.

After all 11 coverages were built, they were combined using the union

command. This combines all attributes of all data contained in every coverage. Once this was completed, one coverage now existed containing all data from all 11 coverages. A new item called 'ngtotal' was added to this coverage's PAT. Using the calculation command, all 11 'ng' items were totaled and this value was stored under the 'ngtotal' item. Any areas which showed an 'ngtotal' value of 0 were still potential landfill sites since they fell out of every no-go zone. Any area which contained a value of 10 or more means it fell within at least one no-go zone and was therefore considered as an unsuitable potential landfill site. The following is specific information on creation of each of these 11 GIS coverages. See Figure 4 for a summary of the RMS accuracy ratings of coverages which were digitized into the database.

The source used for general location of groundwater aquifers was obtained from the Utah Department of Environmental Quality, Division of Water Quality (Anderson et al. 1994). The map titled "Recharge and Discharge Areas" shows primary recharge areas, secondary recharge areas, and discharge areas. Using the Calcomp 9500 digitizer, this map was digitized into the database. An RMS of 0.005 (22.976 meters) was noted. Digitizing errors were manually corrected. The UTM projection system was assigned to the coverage. An item called 'ng1' was added to the PAT. All primary and secondary recharge areas were assigned a value of 10 for item 'ng1'. All discharge areas were assigned a value of 0 for item 'ng1'. Additionally, an item called 'gwtype' was added to the

<u>Coverage</u>	<u>RMS</u>	<u>Meters</u>
Farmlands	0.009	19.1
Floodplains	0.003	12.6
Liquefaction Potential	0.008	9.716
National Forest Boundary	0.006	18.2
Protected Areas	0.006	18.2
Soils	0.006 to 0.052	3.05 to 25.05
Sub-surface Geology	0.019	61.26
Water Recharge / Discharge Zones	0.005	22.976
Zoning	0.008	34.6

Figure 4. Summary of Digitized Maps' Rms Ratings.

PAT to clearly describe the rating of that particular area. Recharge areas were given a 'gwtype' of primary or secondary and discharge areas were given a 'gwtype' of discharge. Using the identity command, the border of Cache County was joined with the recharge zones to create coverage 'rechargecn03'. See Figure 5 for this map.

2. Watercourses

A digital GIS coverage of Cache County surface water systems was obtained through Utah State University Department of Geography. This coverage was copied from Utah Gap analysis CDs included in the Utah Gap Analysis information package (Edwards et al. 1995). It already contained the

UTM projection system.

The researcher decided to place a buffer zone of approximately 100 feet (31 meters) around each side of all watercourses. The figure of 100 to 300 feet as a sufficient buffer zone was suggested by Professor Johnson of Utah State University, Department of Landscape Architecture and Environmental Planning. Mr. Addley at Utah State University, Department of Civil and Environmental Engineering, concurred with this figure, as did Mr. Hoyt of the Bear River Health Department Environmental Division. According to Professor Johnson, 100 feet was usually considered sufficient in an urban environment.

Using the buffer command in ARC, a 31 meter buffer was placed around all watercourses. Watercourses were buffered as lines since they were drawn as lines in the coverage. The areas inside the buffer zone are assigned an inside value of 100 in their PAT. The item 'ng2' was added to the PAT. Areas with an inside value of 100 were selected and using the calculation command, were assigned an 'ng2' value of 10. All other areas outside of the buffer zones were assigned an 'ng2' value of 0.

Using the identity command, the Cache County boundary was combined with the watercourses coverage. This coverage was titled 'wcourses03'. See Figure 6 for this map.

3. Waterbodies

A digital GIS coverage of Cache County surface water systems was

obtained through Utah State University Department of Geography. This coverage was copied from Utah Gap analysis CDs included in the Utah Gap Analysis information package (Edwards et al. 1995). It already contained the UTM projection system.

The same buffer zone of 100 feet, as used for #2 watercourses above, was used for waterbodies. Using the buffer command in ARC, a 31 meter buffer was placed around all waterbodies. Waterbodies were buffered as polygons since they were drawn as polygons in the coverage. The areas inside the buffer zone are assigned an inside value of 100 in their PAT. The item 'ng2a' was added to the PAT. Areas with an inside value of 100 were selected and using the calculation command, were assigned an 'ng2a' value of 10. All other areas outside of the buffer zone were assigned an 'ng2a' value of 0. Using the identity command, the Cache County boundary and waterbodies coverage were combined. This coverage was titled 'wbodies03'. See Figure 7 for this map.

4. Zoning

The zoning information was gathered from the 1995 Zoning Map produced by Cache County Corporation. Per Cache County ordinance #90-15, Chapter 4, Agricultural zone (A), a sanitary landfill is a permitted conditional use in this zone. No other zones permit landfills as a use, therefore, the only potential site locations will have to be located in an agricultural zone.

Using the Calcomp 9500 digitizer, this map was digitized into the

database. An RMS of 0.008 (34.6 meters) was noted. Digitizing errors were manually corrected. The UTM projection system was assigned to the coverage. An item called 'ng3' was added to the PAT. The agricultural zone was assigned an 'ng3' value of 0. All other different zones were assigned an 'ng3' value of 10. Additionally, an item called 'zone_code' was added to the PAT to clearly describe the rating of that particular area. Agriculture zones were given a 'zone_code' of agric. The other zones were given an appropriate 'zone_code' that would readily identify that zone (e.g., comm for commercial zone). Using the identity command, the border of Cache County was joined with the zone coverage to create coverage 'zonecn04'. See Figure 8 for this map.

5. Built-Up Areas With 1/4 Mile Buffer Zone

A digital GIS coverage of Cache County land uses was obtained through Utah State University Department of Geography. This coverage was copied from an existing GIS database in the GIS department. It already contained the UTM projection system. In ARC, all polygons delineated as built-up were reselected out of that coverage to create a separate coverage containing only the built-up areas. State regulations require that a landfill shall not be sited within 1/4 mile of an existing built-up area. The equivalent buffer around existing built-up areas was set at 403 meters.

Using the buffer command, all built-up areas were buffered by 403 meters producing the coverage 'builtbuf403'. Using the identity command, the Cache

County boundary coverage was combined with 'builtbuf403' to produce coverage 'builtbuf403.02'. An item called 'ng4' was added to the PAT. The areas inside the buffer zone are assigned an inside value of 100 in their PAT. Areas with an inside value of 100 were selected and using the calculation command, were assigned an 'ng4' value of 10. All other areas outside of the buffer zones were assigned an 'ng4' value of 0. See Figure 9 for this map.

6. Important Farmlands

The map of important farmlands was obtained from the Logan division of the Natural Resources Conservation Service (NRCS). This map delineates prime farmland, farmland of statewide importance (irrigated), farmland of statewide importance (non-irrigated), additional farmland of local importance, as well as general location of water and urban areas. This map was used as a base map for developing many of the GIS coverages used in this study.

Using the Calcomp 9500 digitizer, this map was digitized into the database. An RMS of 0.009 (19.1 meters) was noted. Digitizing errors were manually corrected. The UTM projection system was assigned to the coverage. An item called 'ng5' was added to the PAT. Using the calculation command, all prime and statewide important farmlands were assigned an 'ng5' value of 10. All other different zones were assigned an 'ng5' value of 0. Additionally, an item called 'farm_code' was added to the PAT to clearly describe the rating of that particular area. Using the identity command, the Cache County boundary

coverage was combined with the farm coverage to produce coverage 'farmcn006'. See Figure 10 for this map.

7. Protected Areas With 1000 Foot Buffer Zone: Wilderness Areas, Wildlife Management Areas, State Recreation Areas

The wilderness area, wildlife management area, and state recreation area information was gathered from the U.S. Forest Service, Logan District. The map used is titled "Wasatch-Cache National Forest, Ogden and Logan Ranger Districts". This map provided information on the boundary lines of these three types of areas in Cache County. The land status shown is valid as of 1992.

Using the Calcomp 9500 digitizer, this map was digitized into the database. An RMS of 0.006 (18.2 meters) was noted. Digitizing errors were manually corrected. The UTM projection system was assigned to the coverage. Using the identity command, the Cache County boundary was combined with the national forest map information to produce coverage 'nforcn03'. An item called 'nfor_code' was added to the PAT. All areas were assigned a recognizable code (e.g., wma for wildlife management area). In ARC, all wilderness, wildlife management, and state recreation areas were selected out and put into

Figure 5. Water Recharge / Discharge Zones.

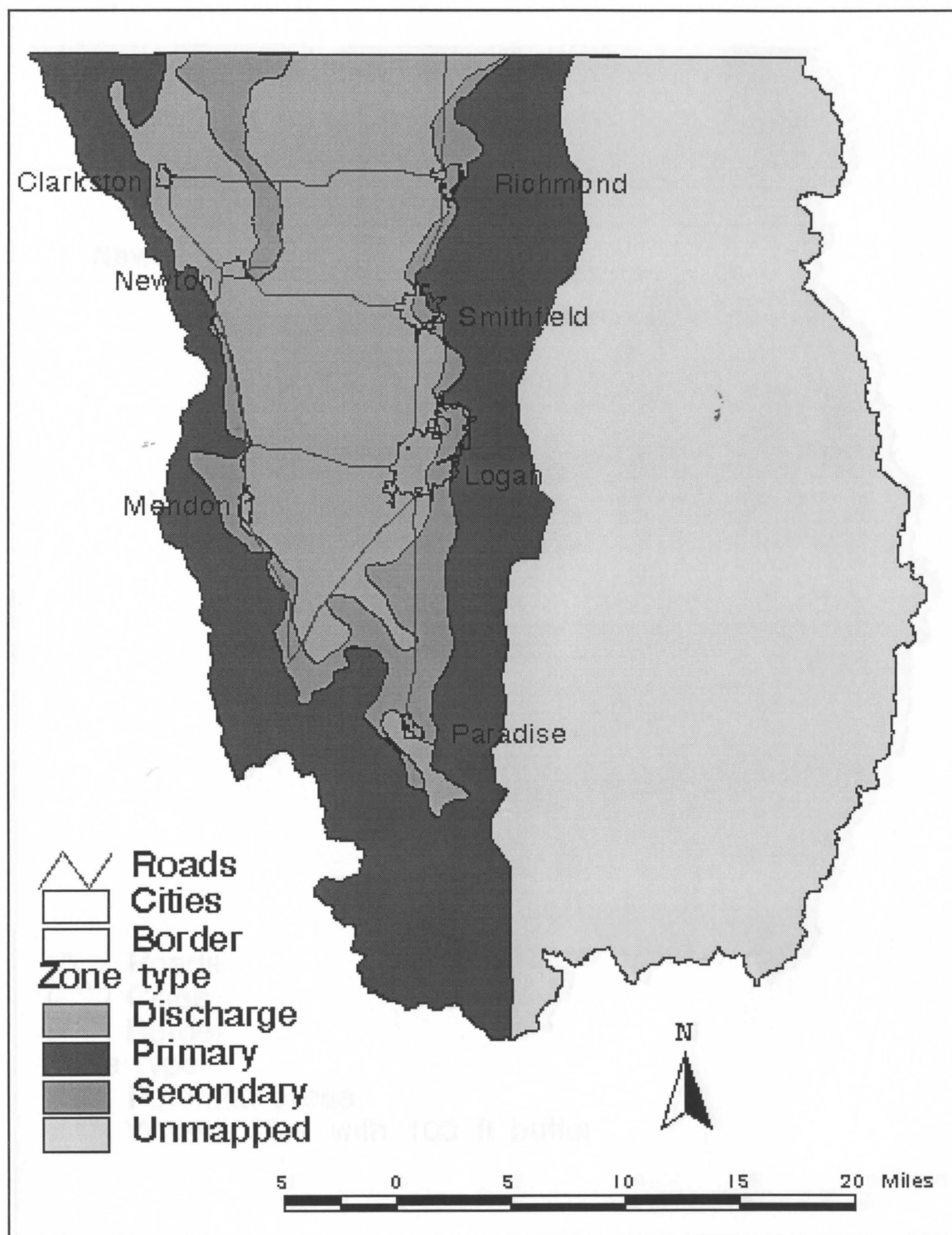


Figure 5. Water Recharge / Discharge Zones.

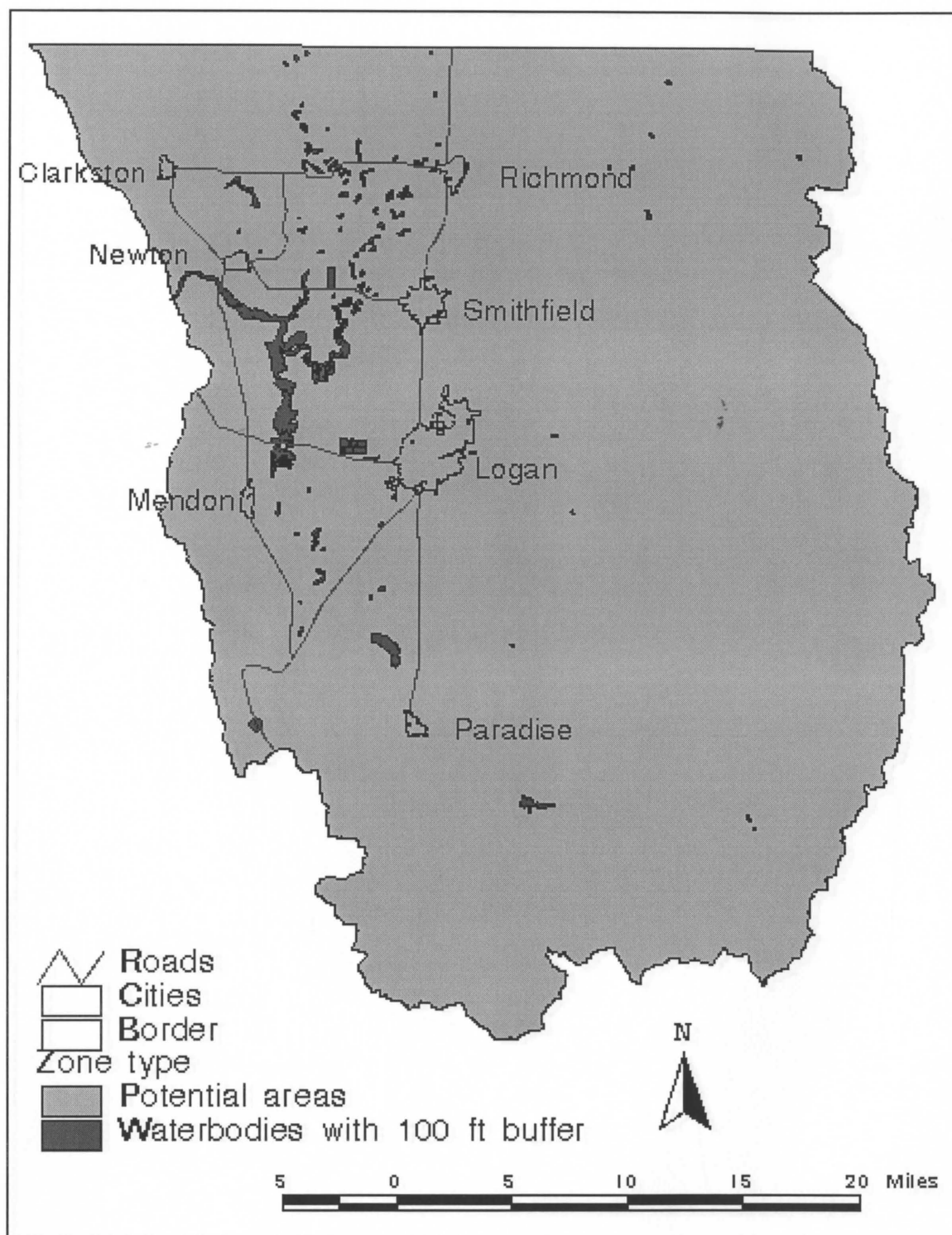


Figure 6. Watercourses with 100 foot buffer zone.

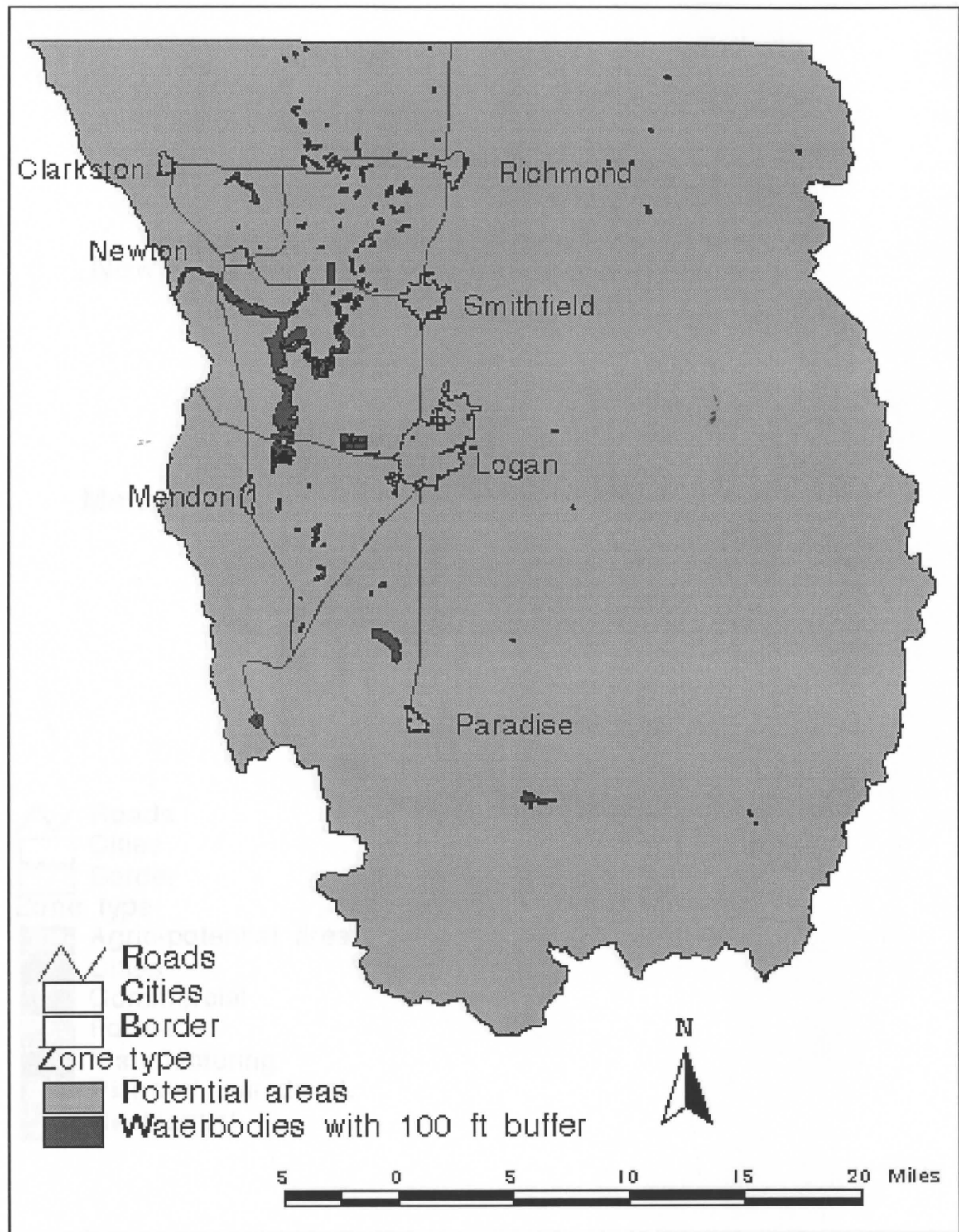


Figure 7. Waterbodies with 100 Foot Buffer Zone.

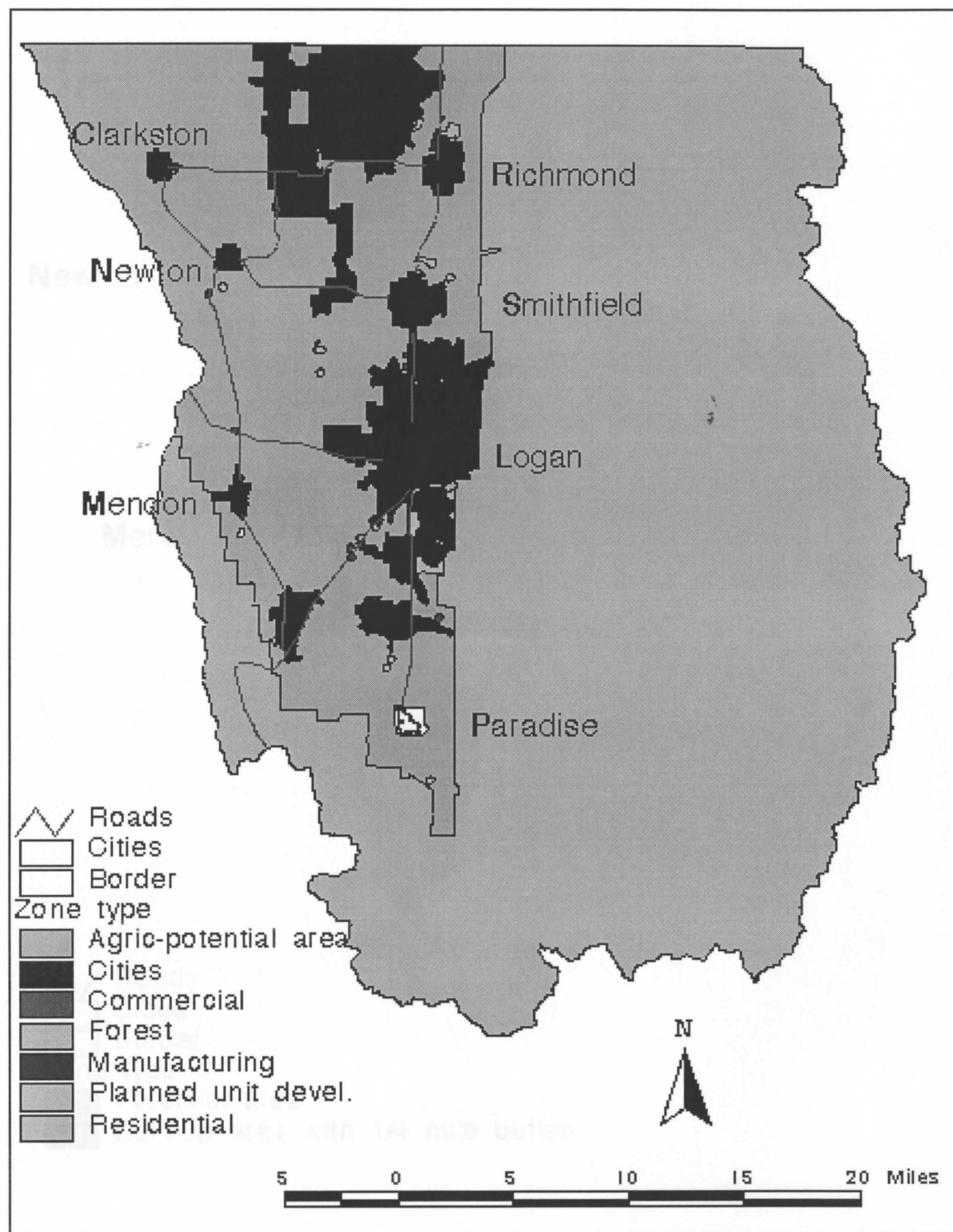


Figure 8. Zoning Map of Cache County.

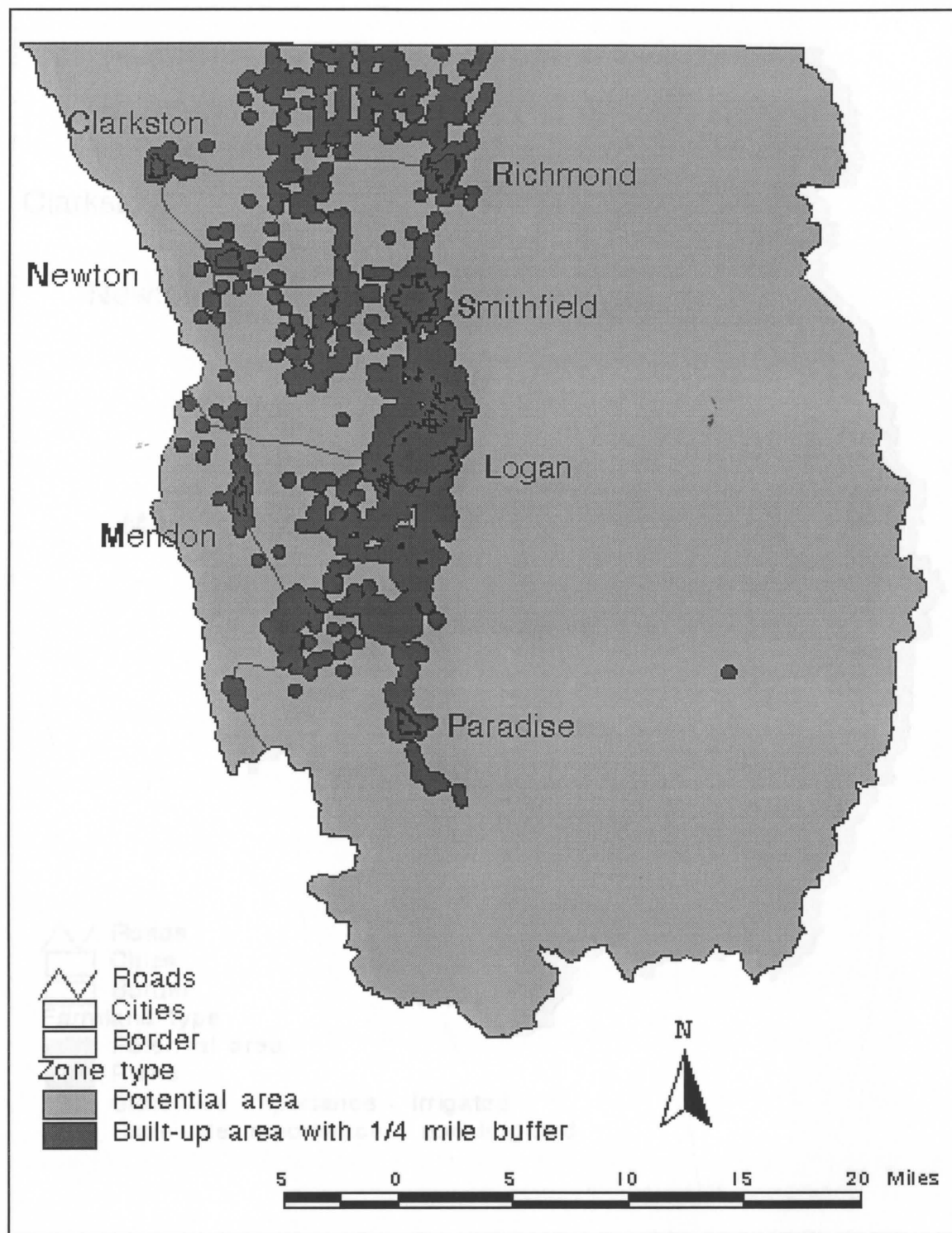


Figure 9. Built-up Areas with 1/4 Mile Buffer Zone.

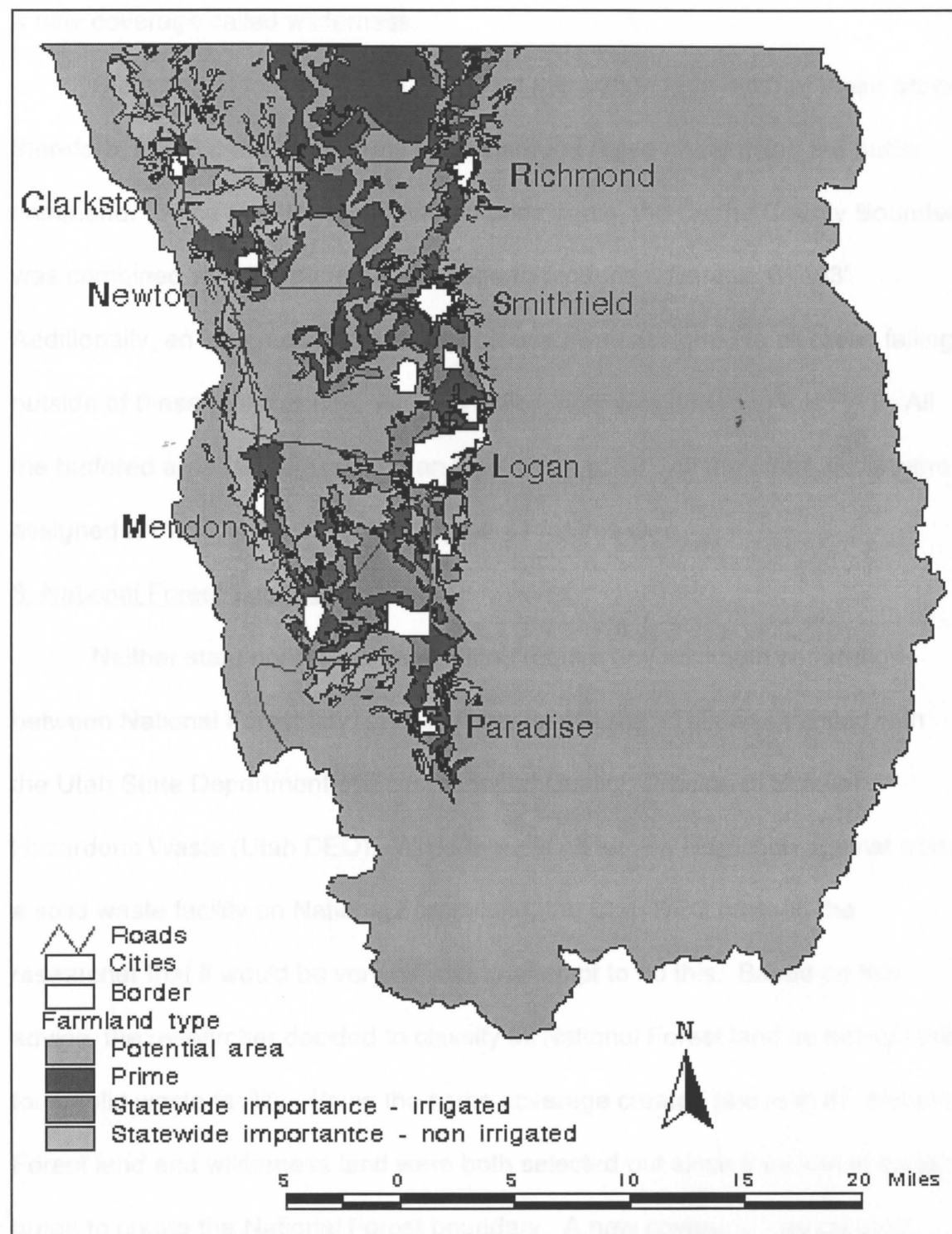


Figure 10. Important Farmlands.

a new coverage called wilderness.

State regulations require a 1000 foot separation from each of these areas, therefore, a 305 meter buffer was placed around these areas using the buffer command. Using the identity command once again, the Cache County Boundary was combined with the buffered coverage to produce coverage 'wild03'. Additionally, an 'nfor_code' of pot (for potential) was assigned to all areas falling outside of these buffer zones. An item called 'ng6' was added to this PAT. All the buffered areas were assigned an 'ng6' value of 10. All the other areas were assigned an 'ng6' value of 0. See Figure 11 for this map.

8. National Forest Boundary

Neither state nor federal regulations require any minimum separation between National Forest land and any new landfill site. This was verified with the Utah State Department of Environmental Quality, Division of Solid and Hazardous Waste (Utah DEQ). While there is no known restriction against siting a solid waste facility on National Forest land, the Utah DEQ advised the researcher that it would be very difficult to attempt to do this. Based on this advice, the researcher decided to classify all National Forest land as not suitable for a solid waste facility. Using the same coverage created above in #7, National Forest land and wilderness land were both selected out since they join at certain areas to create the National Forest boundary. A new coverage was created called 'nfbound'. Using the dissolve command based on the name item in the

PAT, all inside polygons were dissolved and the coverage created represented just the interface boundary between national forest land and non-national forest land. This coverage was called 'nfbound02'. Additionally, an 'nfor_code' of pot (for potential) was assigned to all areas falling outside of the National Forest and an 'nfor_code' of nf (for National Forest) was assigned to all areas within the National Forest boundary.

An item called 'ng6a' was added to the PAT. All areas contained within the National Forest boundary were assigned an ng6a value of 10. All areas not contained within the National Forest boundary were assigned an 'ng6a' value of 0. See Figure 12 for this map.

9. Wetlands: Riparian Zones With 100 Foot Buffer Zone

There is no official wetlands delineation map for Cache County as verified by the U.S. Fish and Wildlife Service (USFWS) in Salt Lake City. Rather, if an area needs to be surveyed for existence of wetlands, the USFWS will do that on a case by case basis. The researcher therefore decided to use Gap analysis data available through Utah State University. A digital GIS coverage of Cache County vegetation was created from data obtained through Utah State University Department of Geography. These data were copied from Utah Gap analysis CDs included in the Utah Gap Analysis information package (Edwards et al. 1995). The data already contained the UTM projection system.

These coverages were not available in county specific data but rather in

quad data. In order to obtain only the county specific data, three quad vegetation data maps were copied to the researcher's home directory. Using the clip command, all three coverages were clipped using the Cache County boundary in order to remove any areas falling outside of the county. Then all three coverages were joined using the mapjoin command and a county specific vegetation coverage was now created. This coverage was called 'vegjoin' and contained all the vegetation data for Cache County.

Since this coverage only required wetlands data, wetlands, lowland riparian, and wet meadow land types were selected out. In this selection process, it was noted that no wet meadows actually existed in the county, so this coverage consists of wetlands and lowland riparian areas only. They shall both be referred to as wetlands.

The same buffer zone of 100 feet, as used for #2 watercourses above, was used for wetlands. Using the buffer command in ARC, a 31 meter buffer was placed around all wetlands. They were buffered as polygons since they were drawn as polygons in the coverage. The areas inside the buffer zone are assigned an inside value of 100 in their PAT. The item 'ng7' was added to the PAT. All wetland polygons were selected and were assigned an 'ng7' value of 10 using the calculation command. All other areas outside of the wetland areas were assigned an 'ng7' value of 0. Using the identity command, the Cache County boundary was combined with the wetlands coverage. This coverage was

titled 'vegbuf31.02'. See Figure 13 for this map.

10. Faults With 200 Foot Buffer Zone

A digital GIS coverage of Cache County fault zones was obtained through Utah State University Department of Geography. This coverage was copied from an existing GIS database in the GIS department. It already contained the UTM projection system. State and federal regulations require that a landfill shall not be sited within 200 feet of an existing Holocene. As per the Department of Geology at Utah State University, this means the fault is approximately one million years old and this would encompass mostly every existing fault zone in Cache County. The researcher decided to use the fault zone coverage as it existed and assume that all faults shown on this coverage should not be within 200 feet of any new landfill site. Using the buffer command, all fault lines were buffered by 61 meters producing the coverage 'faultbuf61'. Using the identity command, the Cache County boundary coverage was combined with 'faultbuf61' to produce coverage 'faultbuf61.02'. An item called 'ng8' was added to the PAT. All fault zones were selected and were assigned an 'ng8' value of 10 using the calculation command. All other areas outside of the fault zone areas were assigned an 'ng8' value of 0. See Figure 14 for this map.

11. Floodplains

State and federal regulations require that a landfill not be sited within a 100 year floodplain unless certain standards of design are met. The researcher

decided that all 100 year floodplains would be eliminated as potential sites for a landfill.

The floodplains information was gathered from the 1995 Sensitive Area Map produced by Cache County Corporation. Using the Calcomp 9500 digitizer, this map was digitized into the database. An RMS of 0.003 (12.6 meters) was noted. Digitizing errors were manually corrected. The UTM projection system was assigned to the coverage.

An item called 'ng9' was added to the PAT. The floodplain areas were assigned an 'ng9' value of 10. All other areas outside of the floodplains were assigned an 'ng9' value of 0. Additionally, an item called 'flood_code' was added to the PAT to clearly describe the rating of that particular area. Floodplains were given a 'flood_code' of flood. The other areas were given a 'flood_code' of noflood. Using the identity command, the border of Cache County was joined with the floodplain coverage to create coverage 'floodcn04'. See Figure 15 for this map.

These 11 individual coverages were then combined into one coverage containing data from all the individual coverages using the union command. This composite coverage was named 'union10'. Using the strategy outlined earlier, all areas with an 'ngtotal' value of zero are still potential sites for a future landfill. Based on the required area from Step 3 above, two new coverages were produced showing potential sites for a 100 year landfill and a 25 year landfill.

See Figures 16 and 17 for these maps.

The minimum area required for a 100 year landfill was calculated at 895.3 acres. The GIS data used for this project is in meters so it was necessary to convert from acres to meters. Using a computerized conversion table found on the Internet under measurement units translation, 895.3 acres converted to 3,623,280 square meters. Using the reselect command in ARC, polygons with an area greater than 3,623,280 square meters were selected from the 'union10' coverage and the new coverage was named 'pot01'. Using the union command, 'pot01' was combined with 'cache_cty' (Cache County boundary) to produce coverage 'pot01bnd'.

There were many unwanted data items in this coverage's PAT which needed to be dropped. First, coverage 'pot01bnd' was copied to coverage 'pot01abnd'. The original coverage was kept in the event any of the data from the unioning process were needed. Using the dropitem command in ARC, all unnecessary PAT items were dropped from coverage 'pot01abnd'. Using the additem command in ARC, a new item called 'acres' was added to the 'pot01abnd' PAT. Using the calc command in ARCEDIT, the equivalent acreage amount was inserted in the 'acres' field of the PAT by dividing the area in square meters by 4046.85.

Using the reselect command in ARC, a new coverage named 'pot01bbnd' was created. This coverage selected out potential landfill sites that were greater

than or equal to 895.3 acres in size and less than 4,000 acres in size. The less than amount was specified in order to avoid selecting the entire surrounding outside polygon area. Finally, coverage 'pot01bbnd' was combined with 'cache_cty' to provide the county border. This new coverage was named 'pot01cbnd'. See Figure 16 for this map

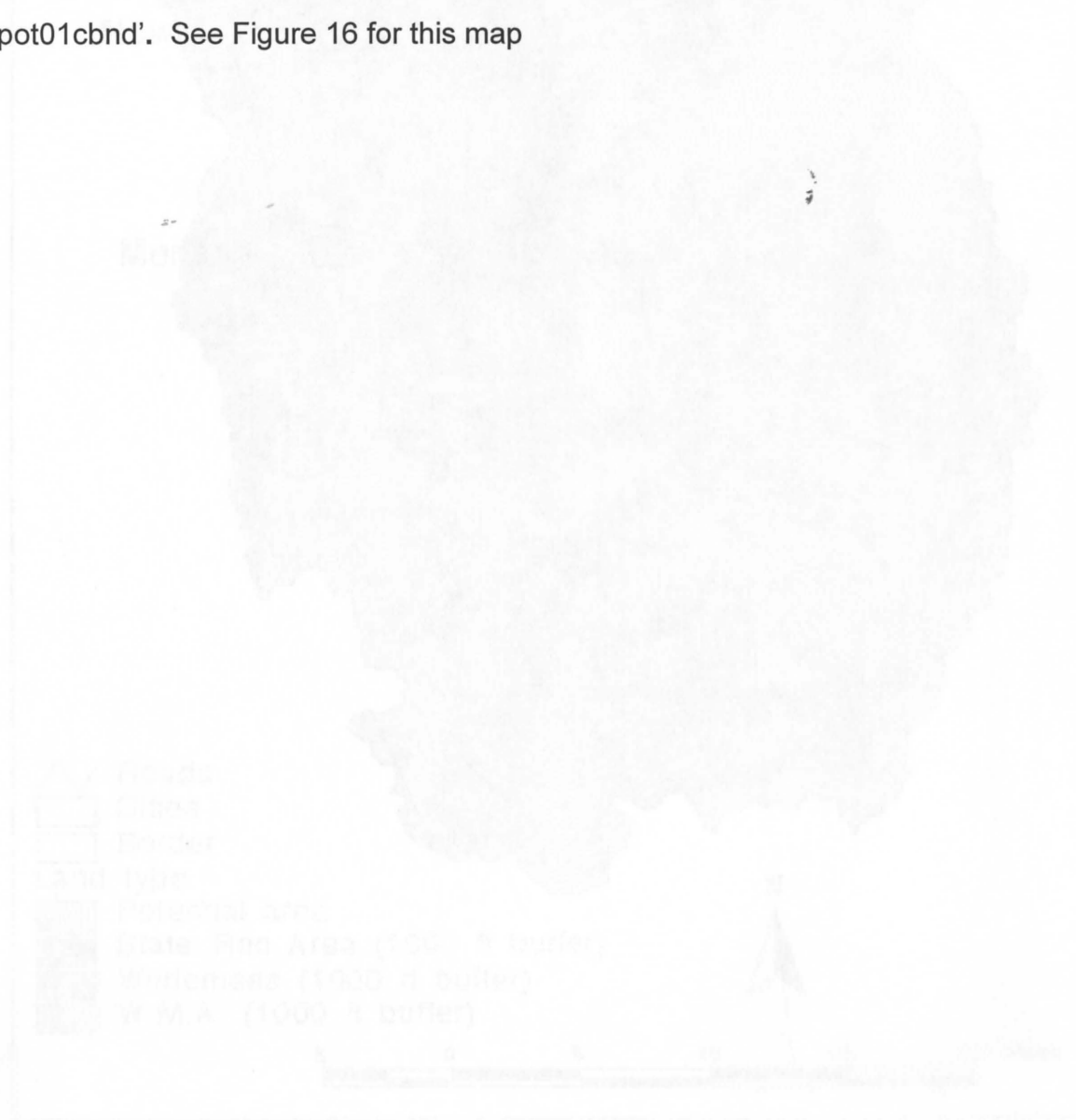


Figure 11. Potential Areas with 1000 Foot Buffer Area

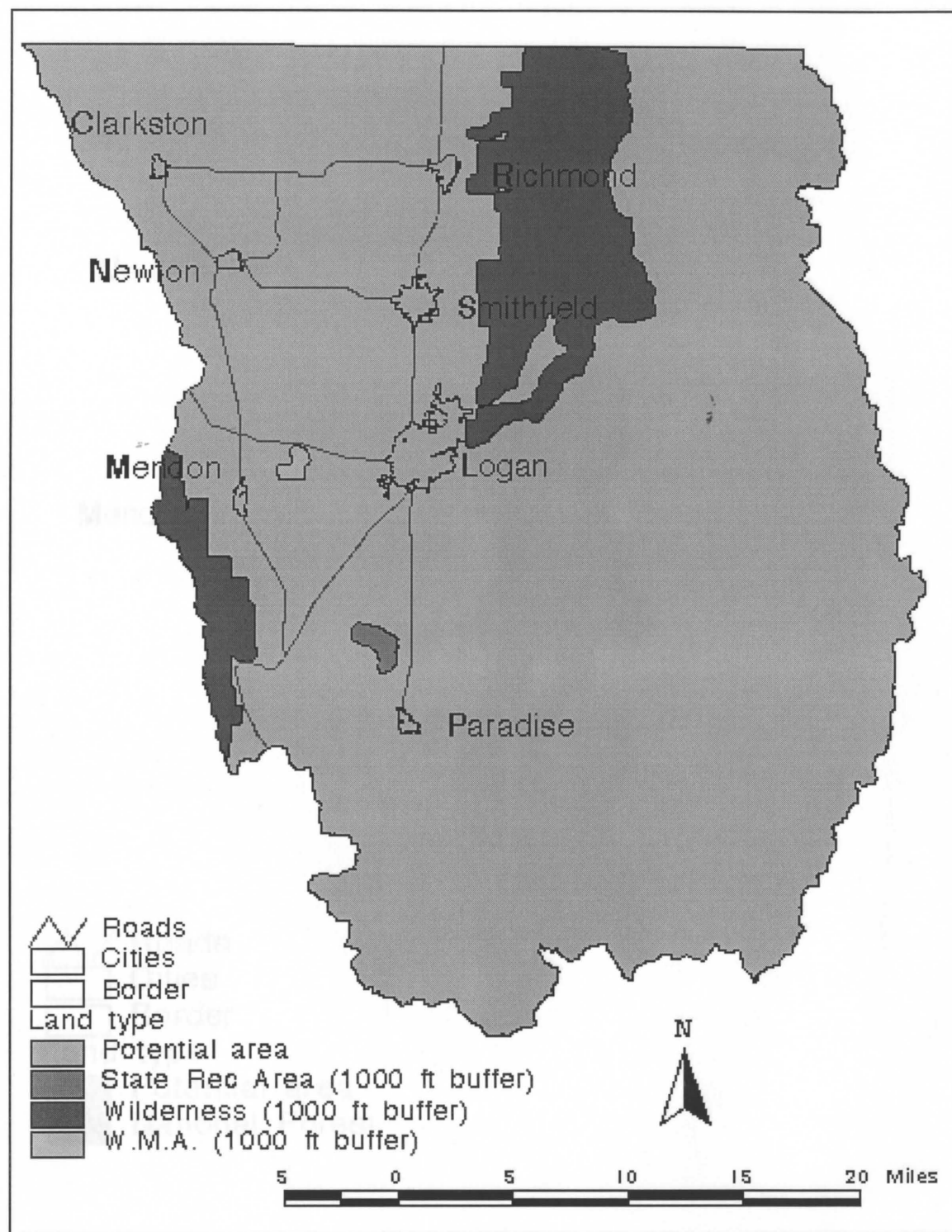


Figure 11. Protected Areas with 1000 Foot Buffer Zone.

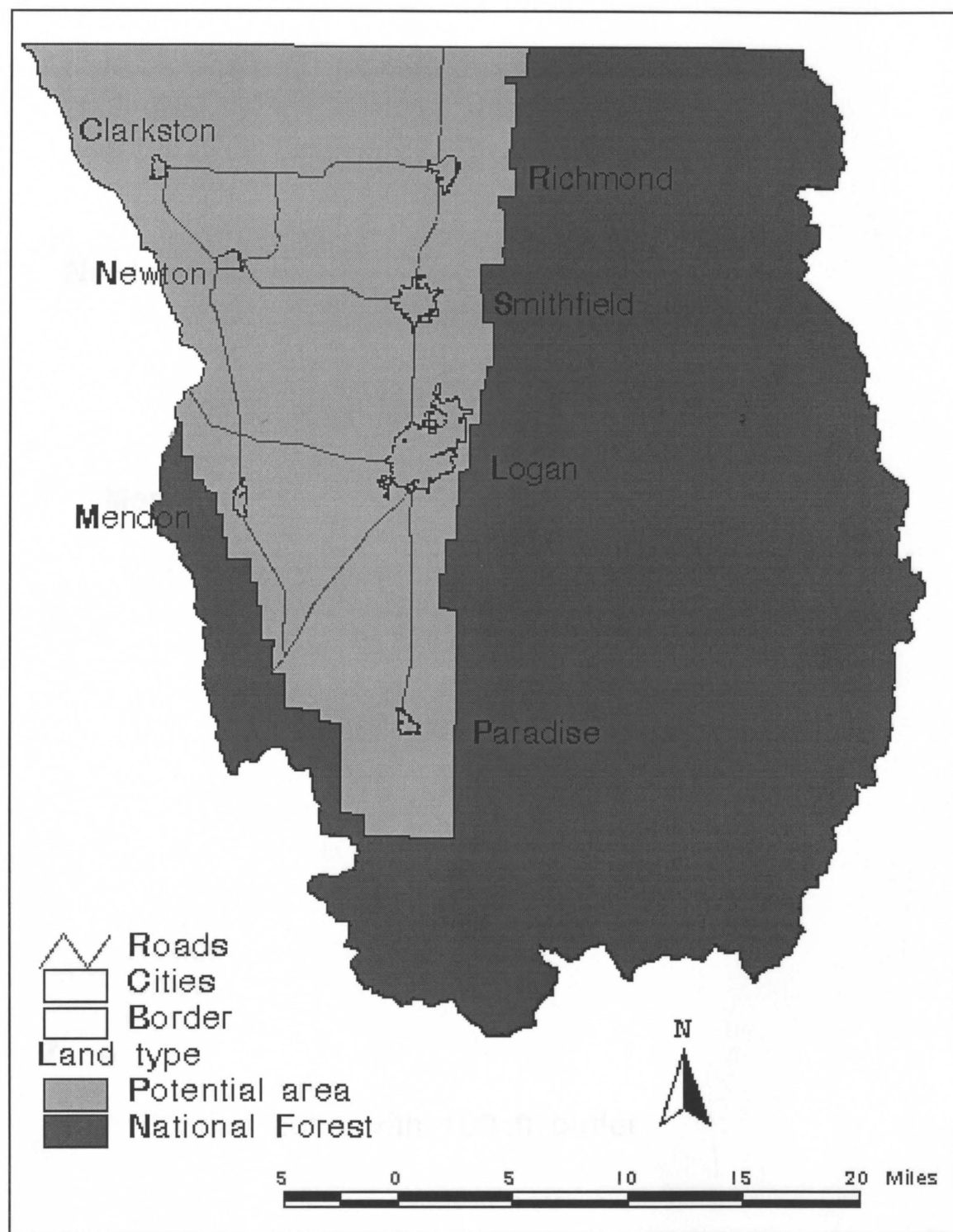


Figure 12. National Forest Boundary.

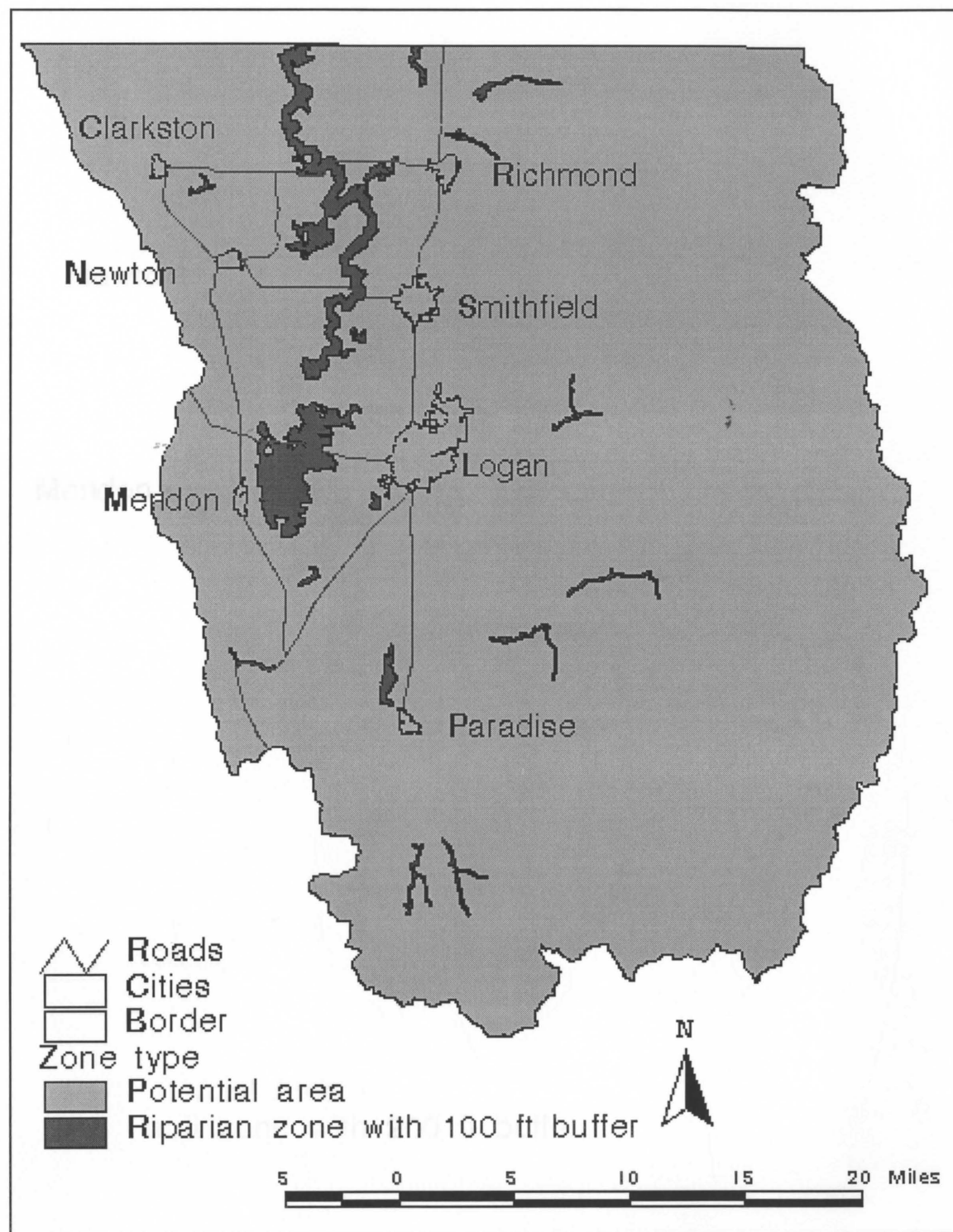


Figure 13. Riparian Zones with 100 Foot Buffer Zone.

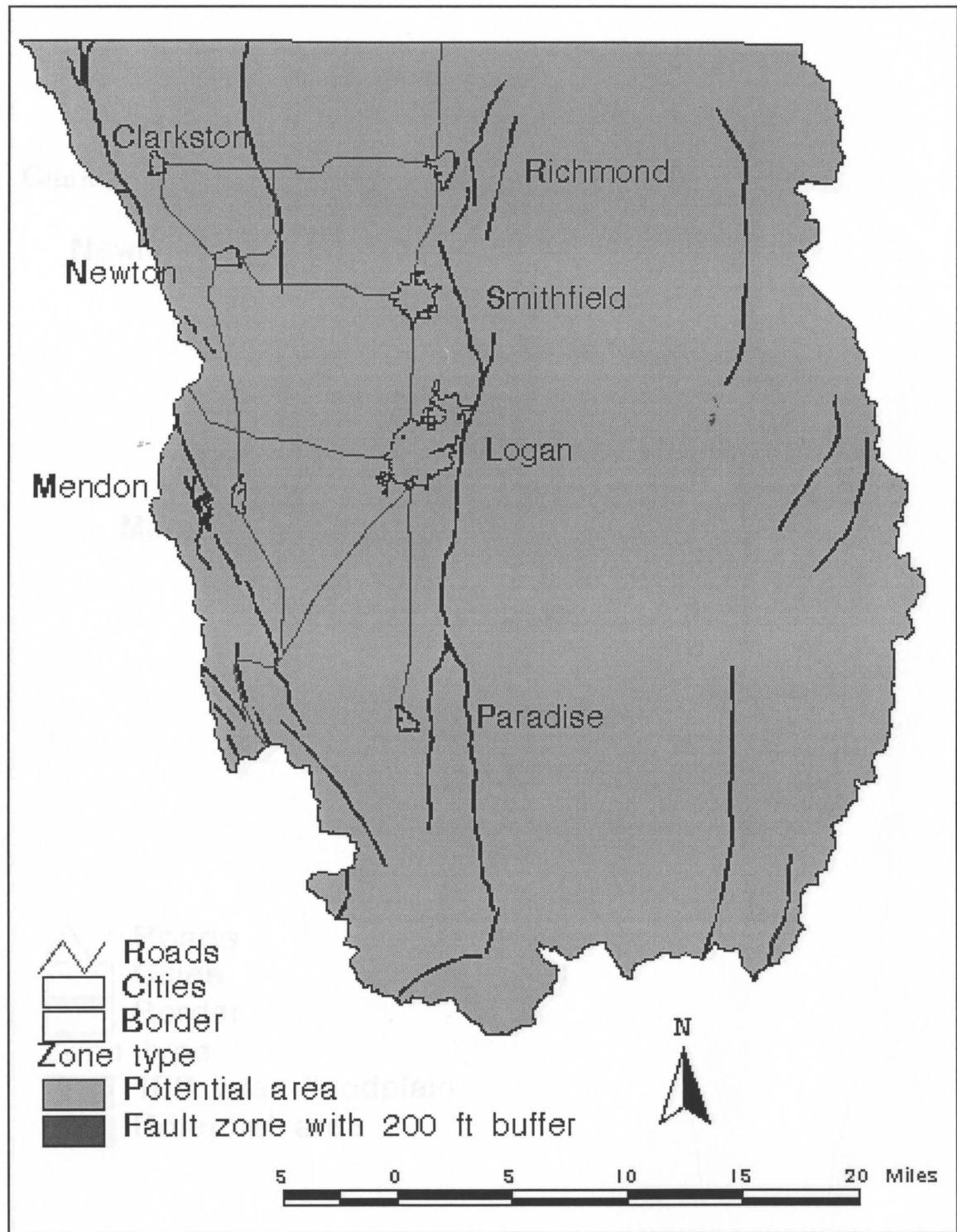


Figure 14. Faults with 200 Foot Buffer Zone.

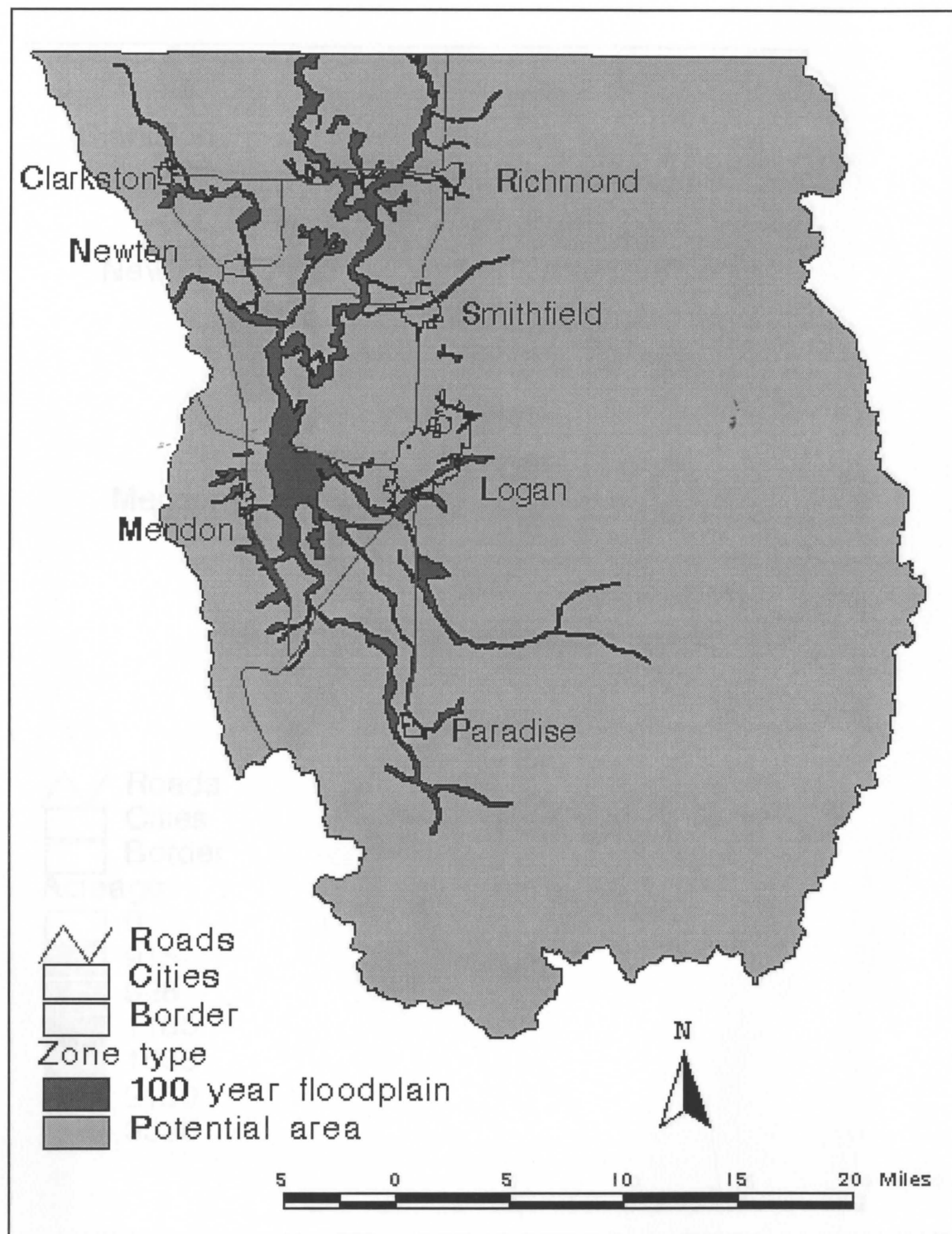


Figure 15. 100 Year Floodplains.

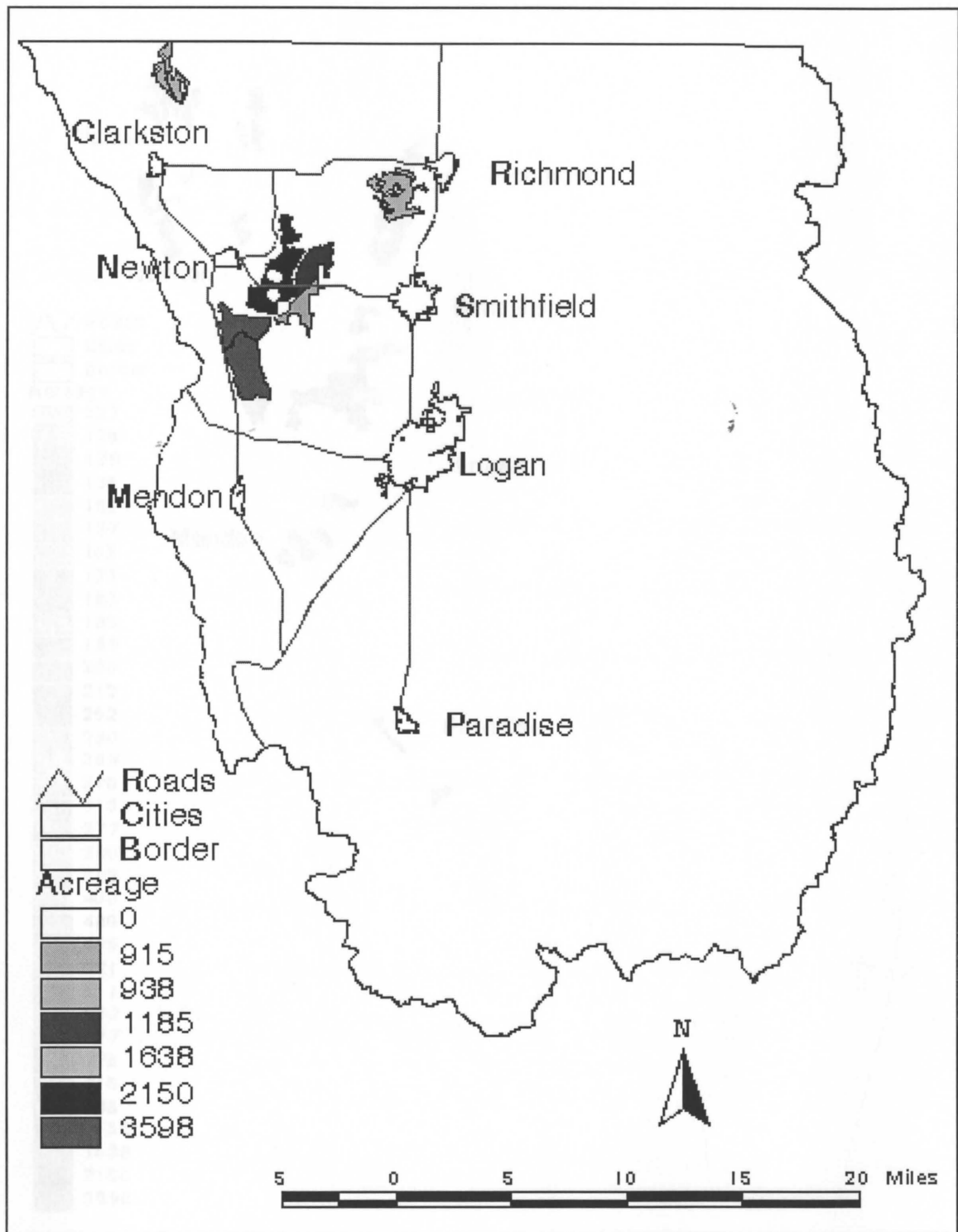


Figure 16. Potential 100 Year Landfill Sites: Preliminary Map.

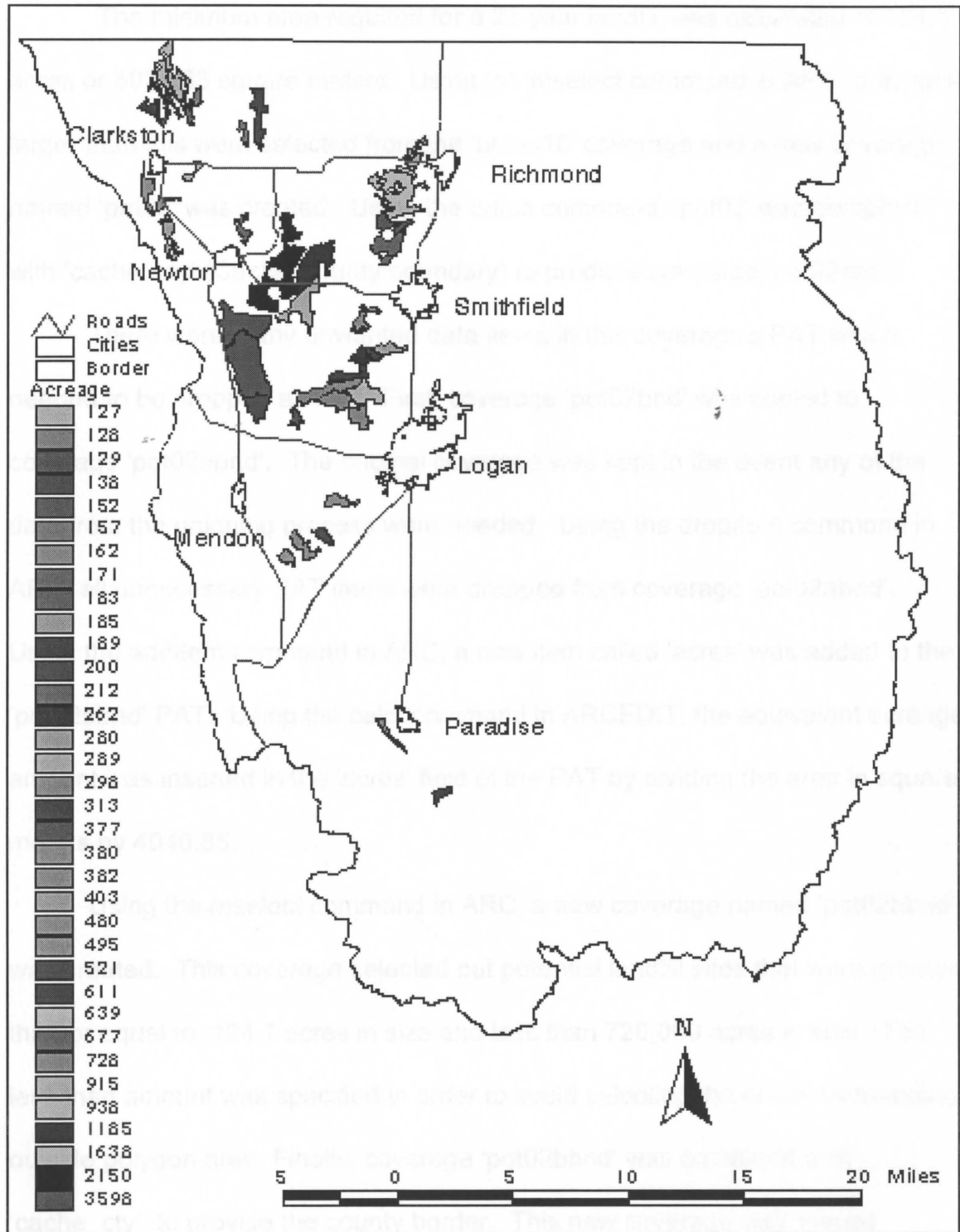


Figure 17. Potential 25 Year Landfill Sites: Preliminary Map.

The minimum area required for a 25 year landfill was calculated at 124.1 acres or 502,233 square meters. Using the reselect command in ARC, polygons larger than this were selected from the 'union10' coverage and a new coverage named 'pot02' was created. Using the union command, 'pot02' was combined with 'cache_cty' (Cache County boundary) to produce coverage 'pot02bnd'.

There were many unwanted data items in this coverage's PAT which needed to be dropped as well. First, coverage 'pot02bnd' was copied to coverage 'pot02abnd'. The original coverage was kept in the event any of the data from the unioning process were needed. Using the dropitem command in ARC, all unnecessary PAT items were dropped from coverage 'pot02abnd'. Using the additem command in ARC, a new item called 'acres' was added to the 'pot02abnd' PAT. Using the calc command in ARCEDIT, the equivalent acreage amount was inserted in the 'acres' field of the PAT by dividing the area in square meters by 4046.85.

Using the reselect command in ARC, a new coverage named 'pot02bbnd' was created. This coverage selected out potential landfill sites that were greater than or equal to 124.1 acres in size and less than 720,000 acres in size. The less than amount was specified in order to avoid selecting the entire surrounding outside polygon area. Finally, coverage 'pot02bbnd' was combined with 'cache_cty' to provide the county border. This new coverage was named 'pot02cbnd'. See Figure 17 for this map.

Step 7 - Assess Potential Landfill Site Maps Produced in Step 6

A meeting was held with Mr. Sunada, Mr Hamud, and Mr. Kingsford, Environmental Health Department Supervisor. This researcher presented, in encapsulated form, the steps taken to produce the two potential landfill site maps. This group decided that in order to provide the most useful product for the Department of Environmental Health and Solid Waste, more in depth evaluation of all the potential 25 year minimum landfill sites would be necessary.

Step 8 - Set Desired Data List For Evaluation of All Potential 25 Year Sites

In this step, a desired data list was developed in order to make a comparative analysis of all potential 25 year sites. This list was previously presented to the group described in Step 7 above. The following desired data items will be considered in order to make a comparative analysis of the potential 25 year sites. These data items are:

- ▶ depth to water table
- ▶ well head location
- ▶ soils
- ▶ slope
- ▶ depth to bedrock
- ▶ subsurface geology
- ▶ liquefaction potential
- ▶ distance to airport
- ▶ prevailing wind patterns in reference to nearby cities
- ▶ potential visual impacts
- ▶ estimated driving time to site from waste centroid (Logan)

Step 9 - Gather Desired Data From List in Step 8 For Evaluation of All Potential 25 Year Sites

In this step, the researcher collected the additional desired data in order to evaluate the potential 25 year sites. The most important data source used was the Soil Survey of Cache Valley Area, Utah (USDA 1974), the most current for the area. The NRCS also has published a companion Sanitary Facilities Report of each soil's suitability for use as an area method landfill, the type under consideration. The Report lists restrictions on the soils suitability for such a landfill. These restrictions are rated as either slight, moderate, or severe. This will be described in greater detail in Step 10. The researcher decided to use this rating system to analyze the potential 25 year landfill sites. Other studies have previously used this rating system or a similar system (Zaporozec and Hole 1976; Lane and McDonald 1983; Ahmed 1989).

The next step was to construct a soils coverage. Originally, this researcher thought that a general soils map could be used in conjunction with the Soil Survey in order to accurately rate the soils of the potential sites. However, it became clear that the best way to produce accurate results would be to digitize all the soils within the potential sites. This information was quite detailed. The researcher gathered the required 25 field chart maps from the NRCS Logan office. In order to correctly coordinate this new soils coverage with the existing potential landfill sites coverage, approximately 104 new registration

tics were recorded in the base coverage. This base coverage of registration tics was then copied over into the new soils coverage.

A coverage called 'soilgridcn01' was digitized from the Soil Survey. This information was taken from the Index to Map Sheets which lists the field charts and the areas of the valley they cover. This coverage made it easier to locate the areas of the field charts which needed to be digitized into the soils coverage.

The soils coverage was then created by digitizing from parts of all 25 field charts, with RMS factors varying from .006 (3.05 meters) to as much as .052 (25.05 meters). These charts are actual air photographs. Since they have not been ortho-rectified, there is an undetermined amount of distortion that develops at the edge of each chart. This was a factor which could not be surmounted within the parameters of this study. Cache County is working on ortho-rectifying and digitizing these soil field charts and they will hopefully be ready for the future phases of the siting process, after completion of this study. An item called 'soilsy', for soil symbol, was added to this coverage. The soil symbol information from each individual polygon was recorded under this item in the coverage's pat. After manually cleaning up errors, several clean and build commands were run on the file to make it ready for analysis. The final soils coverage was called 'soils10'. See Figure 18 for this map.

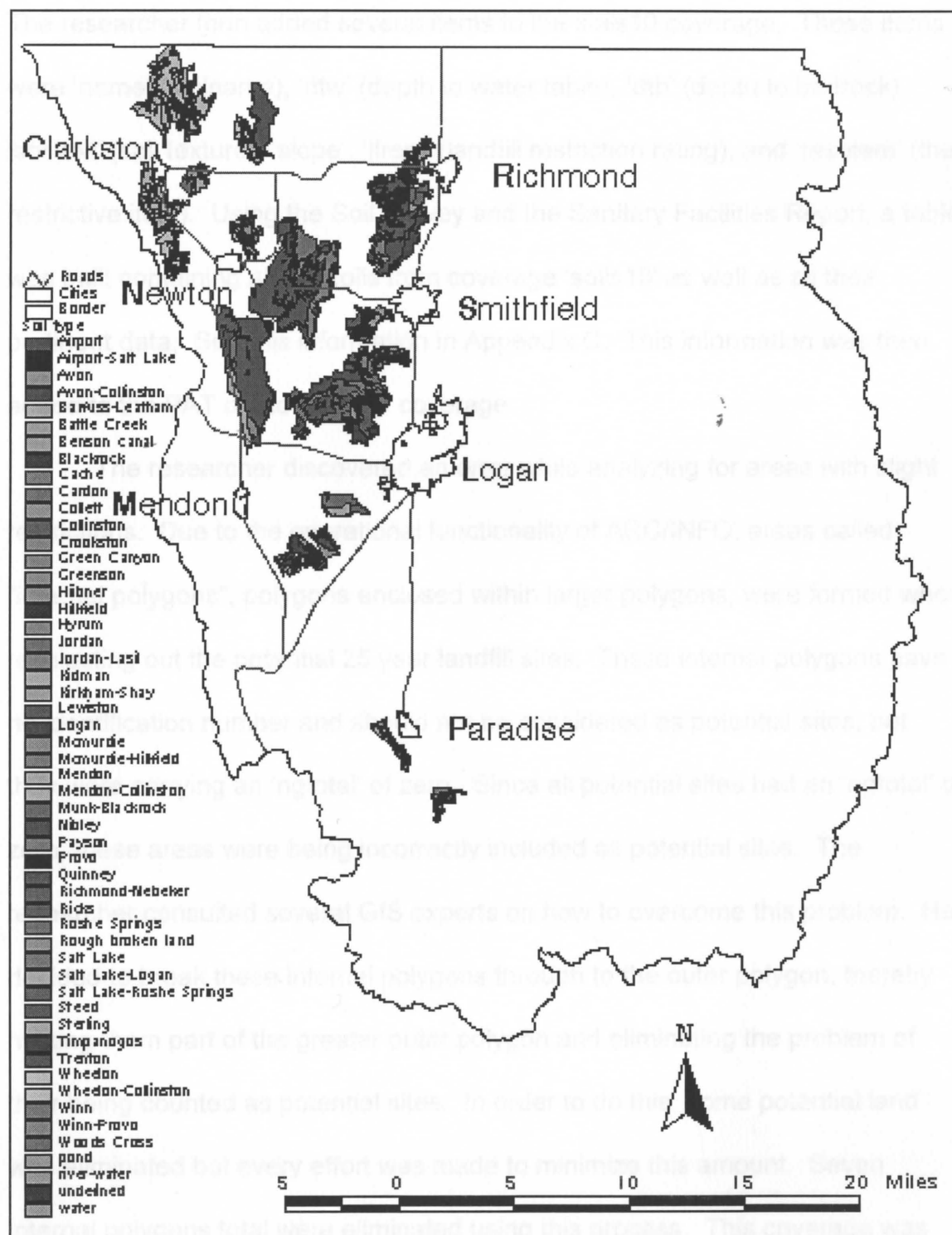


Figure 18. Soils Information for Potential Landfill Sites in Cache County.

The researcher then added several items to the soils10 coverage. These items were 'name' (soilname), 'dtw' (depth to water table), 'dtb' (depth to bedrock), 'soiltext' (soil texture), 'slope', 'lfrest' (landfill restriction rating), and 'restitem' (the restrictive item). Using the Soil Survey and the Sanitary Facilities Report, a table was built containing all the soils from coverage 'soils10' as well as all their pertinent data. See this information in Appendix C. This information was then added to the PAT of the 'soils10' coverage.

The researcher discovered an error while analyzing for areas with slight restrictions. Due to the operational functionality of ARC/INFO, areas called "internal polygons", polygons enclosed within larger polygons, were formed when reselecting out the potential 25 year landfill sites. These internal polygons have no identification number and should not be considered as potential sites, but they were carrying an 'ngtotal' of zero. Since all potential sites had an 'ngtotal' of zero, these areas were being incorrectly included as potential sites. The researcher consulted several GIS experts on how to overcome this problem. He decided to break these internal polygons through to the outer polygon, thereby making them part of the greater outer polygon and eliminating the problem of their being counted as potential sites. In order to do this, some potential land was eliminated but every effort was made to minimize this amount. Seven internal polygons total were eliminated using this process. This coverage was called 'pot02new01'.

The coverage 'pot02new01' was copied to a new coverage 'pot03'. Using the identity command, 'pot03' was overlaid with 'soils10' to produce the new coverage 'pot03a'. An item called 'acres' was added to this coverage. Using the calc command in ARCEDIT, acres were calculated as $\text{area} / 4046.85$.

Step 10 - Evaluate The Potential 25 Year Sites and Produce a List of Sites With Slight, Moderate, and Severe Restrictions For Suitability as an Area Method

Landfill

It was then time to analyze coverage 'pot03a' to see how many areas met the restrictions for soils suitability. The Soils Interpretations Rating Guide published by the NRCS defines the rating "slight", "moderate", and "severe." Chapter 620.03, Rating Terms, gives a description of the limitation ratings. A "slight" rating is given to soils that have properties favorable for the indicated use. The degree of limitation is minor and can be overcome easily. Good performance and low maintenance can be expected. A "moderate" rating is given to soils that have properties moderately favorable for the indicated use. This degree of limitation can be overcome or modified by special planning, design, or maintenance. A "severe" rating is given to soils that have one or more properties unfavorable for the indicated use. This degree of limitation generally requires major soil reclamation, special design, or intensive maintenance. It is usually difficult and costly to compensate for this limitation. According to Mr. Grow of Logan's NRCS, these ratings have been successfully used in court

cases when legal issues depended on soil ratings.

Chapter 620-52 (e), Table 620-20, of the Soil Interpretations Rating Guide gives a detailed description of these limitations. There are eight properties which are rated as restrictions. This limitations table was used to analyze the potential sites. See Figure 19 for details.

The first coverage built was analyzing for areas with only slight restrictions. Using the reselect command in ARC, a new coverage called 'pot03slight' was created. All polygons with an 'lfrest' rating of slight were reselected out. They were then dissolved to combine areas where two different soils with the same slight restriction abutted each other. This produced 176 polygons and the coverage was called 'pot03sltdis'. This coverage now required a new calculation of each polygons acreage. An item called 'acres01' was added to 'pot03sltdis' and using ARCEDIT, 'acres01' was calculated.

The final coverage called 'pot03sltgt0' was created and shows 90 potential sites, none of them large enough for a landfill. Moreover, the sites with restrictions rated as slight are scattered throughout the valley, making it virtually impossible to combine several small sites into one larger site. The largest acreage available with slight restrictions was a 55 acre site northeast of Newton. The only area where this could possibly be done would be for some sites north of Clarkston. However, this researcher was looking for single sites that would accommodate a landfill. These scattered sites would have to be examined in

another study outside the bounds of this project. See Figure 20 for this map.

The next coverage built was analyzing for potential sites with moderate restrictions. In ARC, using the reselect command and coverage 'pot03a', all polygons with moderate restrictions were reselected out and coverage 'pot03mod' was created. Dissolving again for adjoining polygons with the same suitability rating, coverage 'pot03moddis' was created showing 97 polygons. An item called 'acres02' was added to this coverage and 'acres02' was calculated.

The reselect command was used in ARC to reselect out all polygons greater than 124 acres. This new coverage was called 'pot03modgt124'. This coverage shows 14 separate polygons which are at least 124 acres large and contain moderate restrictions. Unfortunately, all of these polygons are composed of Trenton soil which has a high water table and has the moderate restriction due to wetness. The researcher reexamined his results to see if there were some areas with moderate restrictions such as slope only, but there were none. State regulations require a minimum 5 feet depth to water table for any new landfill. See Figure 21 for this map.

The final analysis map of this portion of the study shows areas with severe restrictions. In ARC, using the reselect command and coverage 'pot03a', all polygons with severe restrictions were reselected out and coverage 'pot03sev' was created. Dissolving again for adjoining polygons with the same suitability

rating, coverage 'pot03sevdiss' was created showing 53 polygons.

An item called 'acres03' was added to this coverage and 'acres03' was calculated.

The reselect command was used in ARC to reselect out all polygons greater than 124 acres. This new coverage was called 'pot03sevgt124'.

This coverage shows 26 separate polygons at least 124 acres large which contain severe restrictions. None of these sites should be considered since most have one or more of the following severe restrictions: very high water table, slopes greater than 15 %, flooding potential, or low depth to bedrock. See Figure 22 for this map.

Figure 19. Soil Interpretations Rating Guide, Table B20-20, Sanitary Landfill (Area) (MSD-W-0001, Rev. 1993).

Property	Limits			Restrictive Feature
	Slight	Moderate	Severe	
1. USDA Texture	---	---	Ice	Permafrost
2. Flooding	None	Rare	Freq, Occas	Flooding
3. Depth to Bedrock (inches) (For non aridisols & aridic subgroups)	>60	40-60	<40	Depth to Rock
4. Depth to Cemented Pan (inches) (For non aridisols & aridic subgroups)	>60	40-60	<40	Cemented Pan
5. Permeability (inches/hr, 20-40") (For non aridisols & aridic subgroups)	---	---	>2.0	Seepage
6. Ponding	---	---	+	Ponding
7. Depth to High Water Table Apparent (Ft)	>5	3.5-5	<3.5	Wetness
7a. Depth to High Water Table Perched (Ft)	>3	1.5-3	<1.5	Wetness
8. Slope (Pct)	<8	8-15	>15	Slope

Figure 19. Soil Interpretations Rating Guide, Table 620-20, Sanitary Landfill (Area) (430-vi-nssh, Nov. 1993).

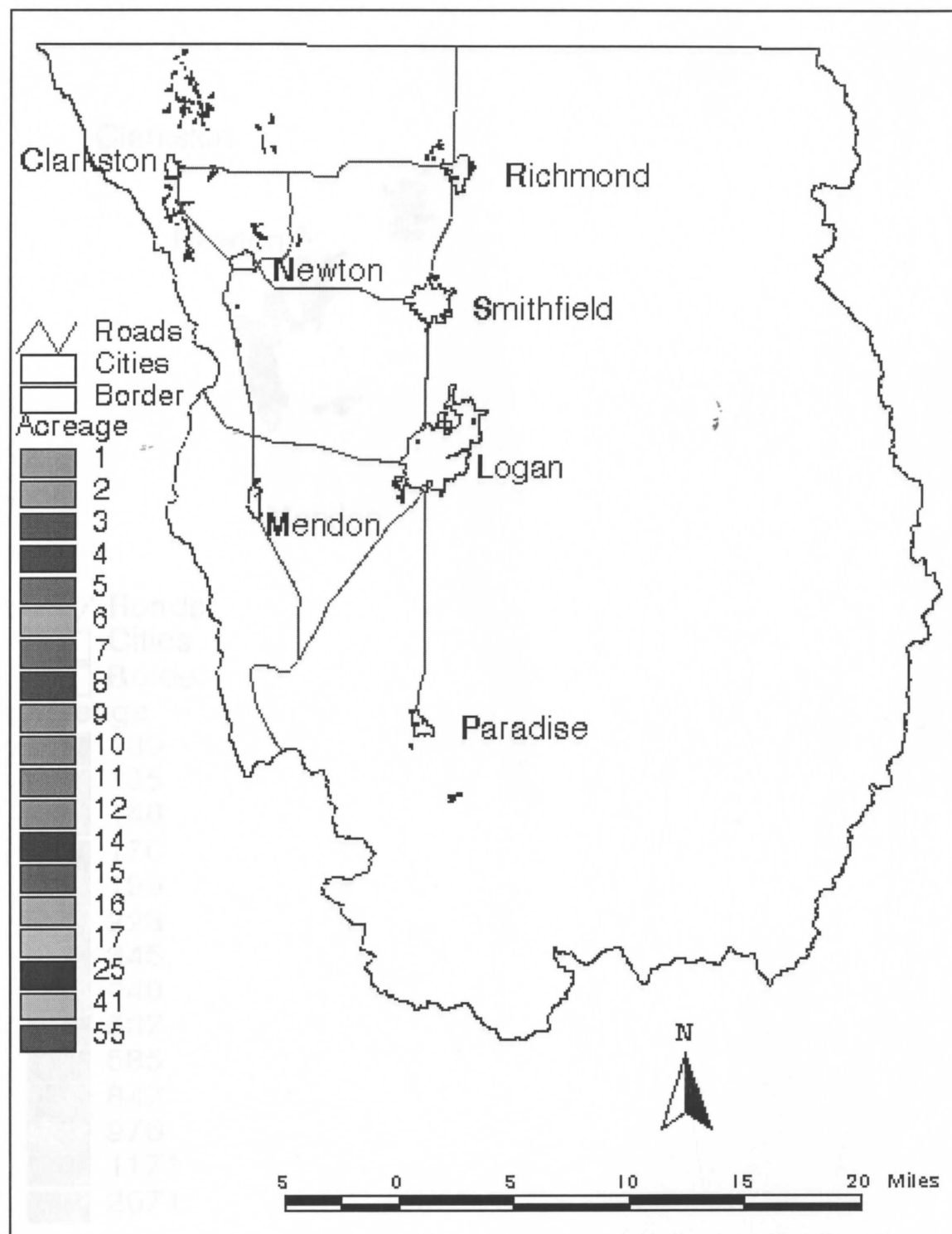


Figure 20. Potential Sites: Slight Restrictions.

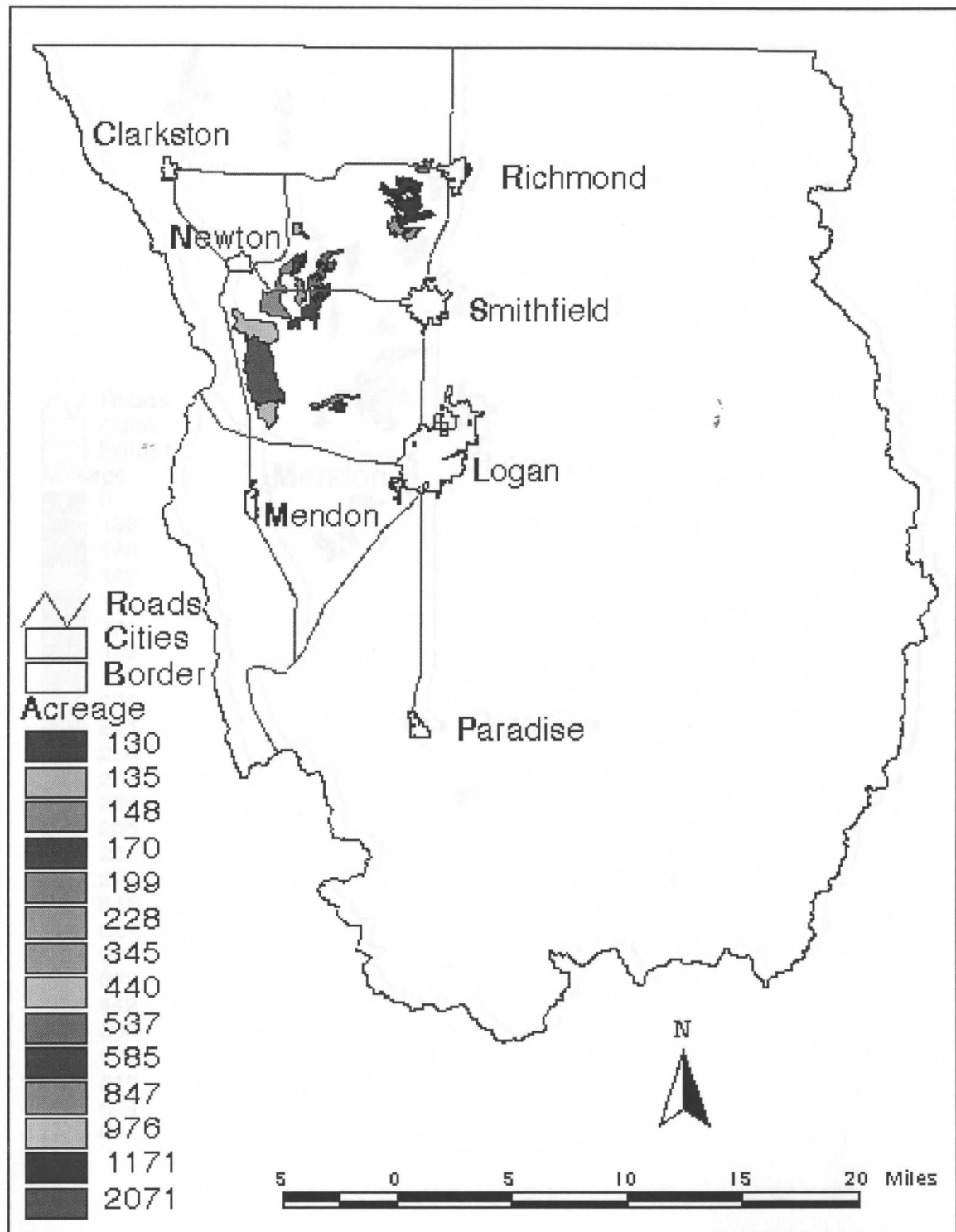


Figure 21. Potential Sites: Moderate Restrictions.

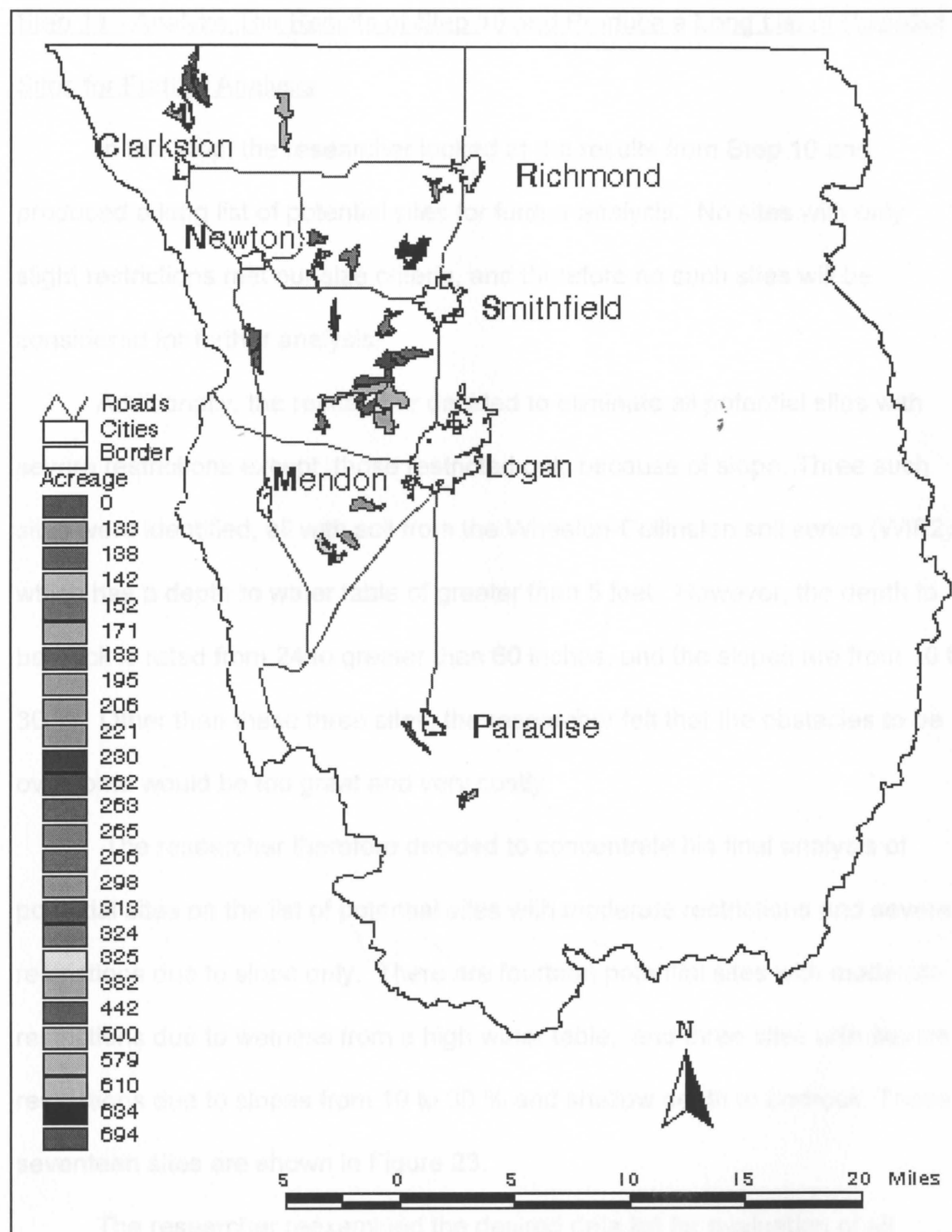


Figure 22. Potential Sites: Severe Restrictions.

Step 11 - Analyze The Results of Step 10 and Produce a Long List of Potential Sites for Further Analysis

In this step, the researcher looked at the results from Step 10 and produced a long list of potential sites for further analysis. No sites with only slight restrictions met our size criteria, and therefore no such sites will be considered for further analysis.

Additionally, the researcher decided to eliminate all potential sites with severe restrictions except those restricted only because of slope. Three such sites were identified, all with soil from the Wheelon-Collinston soil series (WIE2) which has a depth to water table of greater than 5 feet. However, the depth to bedrock is rated from 24 to greater than 60 inches, and the slopes are from 10 to 30 %. Other than these three sites, the researcher felt that the obstacles to be overcome would be too great and very costly.

The researcher therefore decided to concentrate his final analysis of potential sites on the list of potential sites with moderate restrictions and severe restrictions due to slope only. There are fourteen potential sites with moderate restrictions due to wetness from a high water table, and three sites with severe restrictions due to slopes from 10 to 30 % and shallow depth to bedrock. These seventeen sites are shown in Figure 23.

The researcher reexamined the desired data list for evaluation of all potential 25 year sites as outlined in Step 8. The following items required

analysis:

- ▶ 1. depth to water table
- ▶ 2. well head location
- ▶ 3. slope
- ▶ 4. depth to bedrock
- ▶ 5. subsurface geology
- ▶ 6. liquefaction potential
- ▶ 7. distance to airport
- ▶ 8. prevailing wind patterns in reference to nearby cities
- ▶ 9. potential visual impacts
- ▶ 10. estimated driving time to site from waste centroid (Logan)

The researcher decided to give each potential site either a primary or secondary rating for each of these 10 factors, based on how well the site meets the criteria established for each factor. He then established a table showing each site's overall ranking for each of these factors. The sites with the highest potential will be those with the most primary ratings.

Figure 23. Potential Landfill Sites: Final Map.

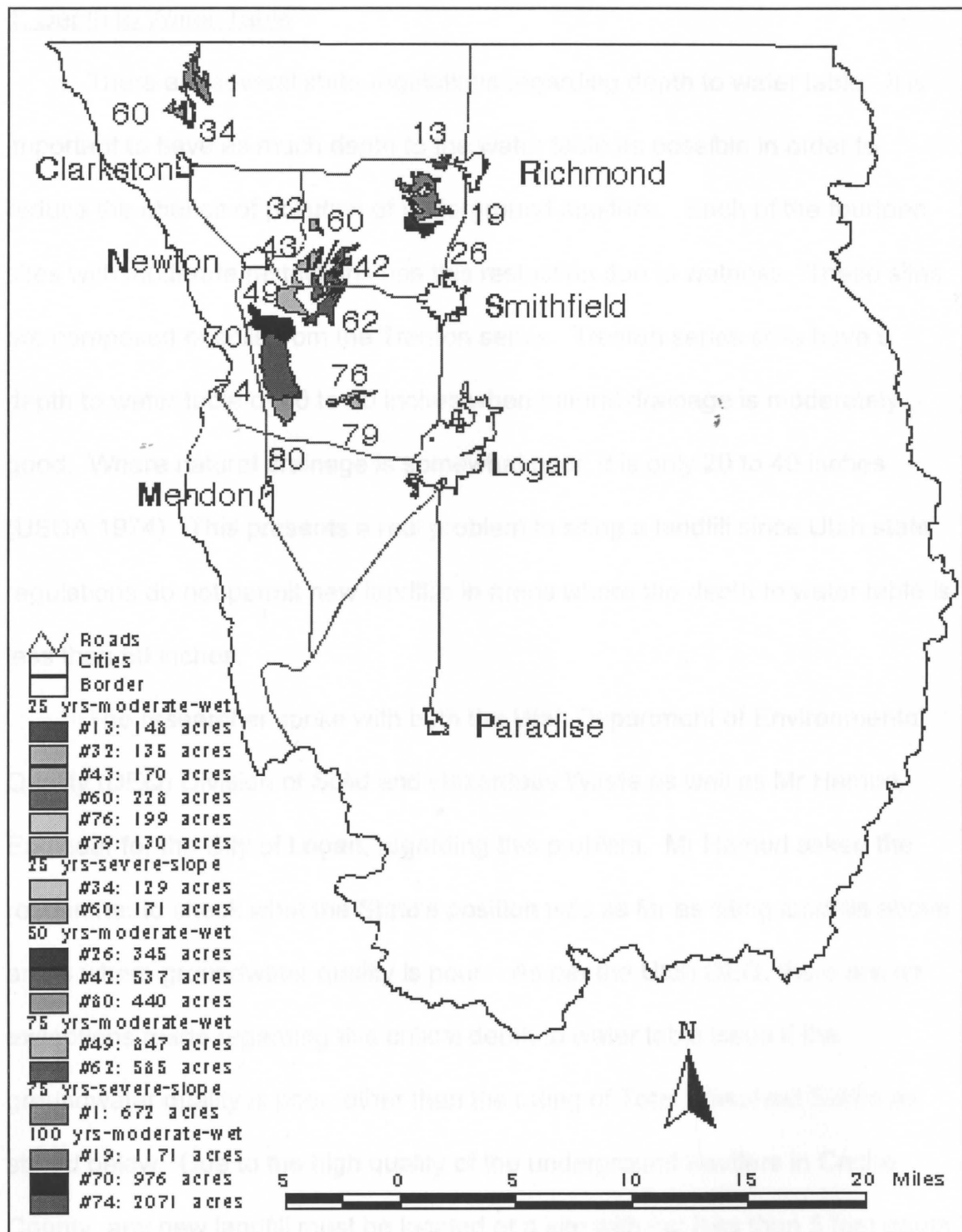


Figure 23. Potential Landfill Sites: Final Map.

1. Depth to Water Table

There are several state regulations regarding depth to water table. It is important to have as much depth to the water table as possible in order to reduce the chance of pollution of underground aquifers. Each of the fourteen sites with moderate restrictions has this restriction due to wetness. These sites are composed of soils from the Trenton series. Trenton series soils have a depth to water table of 40 to 60 inches when natural drainage is moderately good. Where natural drainage is somewhat poor, it is only 20 to 40 inches (USDA 1974). This presents a real problem to siting a landfill since Utah state regulations do not permit new landfills in areas where the depth to water table is less than 60 inches.

The researcher spoke with both the Utah Department of Environmental Quality (DEQ) Division of Solid and Hazardous Waste as well as Mr Hamud, Engineer for the City of Logan, regarding this problem. Mr Hamud asked the researcher to check what the State's position was as far as siting landfills above areas where groundwater quality is poor. As per the Utah DEQ, there are no exceptions made regarding this critical depth to water table issue if the groundwater quality is poor, other than the rating of Total Dissolved Solids as stated below. Due to the high quality of the underground aquifers in Cache County, any new landfill must be located at a site with not less than 5 feet depth to the historical high level of groundwater (see Appendix A, R315-302-1.(2) (e)

Ground Water (I) (A). There are exceptions where aquifers contain groundwater with a Total Dissolved Solids (TDS) of 10,000 mg/L or less, but a study by Anderson et al. (1994, p 12) reports TDS ratings in Cache Valley range between less than 500 to less than 1,000 mg/L.

Moreover, any new landfill in Cache Valley must be constructed with a composite liner. Utah Solid Waste Permitting and Management Rules R315-302-1.(2) (e) groundwater (iv) (A) & (B) would probably require a depth to groundwater of either 50 or 100 feet if a composite liner were not used in the case of Cache Valley, based on the low TDS groundwater amounts.

One possible solution to the depth to groundwater problem would be to build up the base of the landfill. For example, if the site had a depth to groundwater of 3 feet, an additional 2 feet of new soil could be placed on top of the site and this would fulfill the requirement of 5 feet. This was verified as an acceptable remediation method by both the Utah DEQ and Mr. Hamud. The costs of such site remediation would be high. Site-specific testing is necessary to verify if this action would have to be taken with these sites. These fourteen sites therefore are rated as secondary sites based on depth to groundwater.

The three sites with severe restrictions due to slope have a depth to groundwater of greater than 60 inches. There would therefore be no groundwater problem with these sites. These three sites therefore are rated as primary sites based on depth to groundwater.

2. Wellhead Location

Utah Solid Waste Permitting and Management Rules R315-302-1.(2) (e) groundwater (v) states that “no new facility shall be located in designated drinking water source protection or, if no source protection area is designated, within a distance to existing drinking water wells or springs for public water supplies of 250 days ground water travel time”. The researcher checked with Mr. Atkins at the Logan office of Division Of Natural Resources Water Rights Department. As per Mr. Atkins, there are no existing drinking water source protection areas designated in Cache County. Logan City is working on developing one for its drinking water per Mr. Hamud, Logan City Engineer.

The researcher clarified the above quotation with Utah DEQ Division of Solid and Hazardous Wastes. As per Mr. Emmons, the drinking water wells as well as the springs must both be classified as public water supplies. Both Mr. Emmons and Mr. Atkins believed that the official definition of public drinking water source means that it must serve at least 15 people. Based on this information, the researcher showed the potential sites to Mr. Atkins. Only one public drinking well exists and is located southwest of Richmond. This well serves the community of Richmond. No other public drinking wells or springs exist in Cache County.

Suggestions of distance for separation of wellheads from landfills vary from less than 100 feet to over 6,000 feet, depending on the local geology and

soils (Zaporozec and Hole 1976; Wathen et al. 1987) The Trenton series soils are silty clay loam and hold water well. Their permeability rating is from 0.06 to 0.2 inches per hour (USDA 1974). In order to try to get a feel for what 250 days groundwater travel time would be this study, the researcher did a simple math calculation. The maximum rate of 0.2 inches per hour times 24 hours per day yields a travel distance of 4.8 inches per day. Multiplying this by 250 days equals 1,200 inches or approximately 100 feet.

The researcher decided to be much more conservative in his approach to groundwater protection. He decided to measure distances from the one well at 1,000 foot increments, to a maximum of 5,000 feet from the well head. In order to create the wellhead location analysis map, he first digitized the well location into ARCINFO with an RMS of 0.51 (25.1 meters). The initial coverage was called 'wells'. The clean command was run on this coverage and the coverage 'wells01' was created. He then built individual coverages of separation distance of 1,000 through 5,000 feet. These individual coverages were then joined using the union command and the final coverage was called 'wells05'. In ARCEDIT, an item called 'distance' was added and each distance polygon was assigned its proper value. The results are shown in Figure 24, Analysis: Distance From Public Drinking Wells & Springs.

Only one site is located within this buffer zone. Site 13 is located approximately 2,000 feet from the Richmond well. Site 13 is therefore rated as

a secondary site based on wellhead location. All other potential sites are located outside of the well buffer zone and are therefore rated as primary sites based on wellhead location.

3. Slope

Slope information was gathered from the 1974 Soil Survey of Cache Valley (USDA 1974). All 14 potential sites with moderate restrictions have Trenton series soils. These soils have slope ratings of 0 to 2 % (TrA), 2 to 4 % (TrB), 4 to 8 % (TrC), and 8 to 20 % (TrD2). Sites with only TrA, TrB, and/or TrC soils are preferred since the slopes are all less than 8 %. This is considered a slight restriction to constructing an area method landfill, based on the USDA/NRCS Soils Interpretations Rating Guide. Sites with soil type TrD2 are secondary choices due to the higher slopes.

Potential sites numbered 13, 19, and 26 contain TrD2 soils and are therefore rated as secondary sites based on slope since their limitation rating for slope could be either moderate or severe, based on the site. The remaining 11 potential sites with moderate restrictions are rated as primary sites based on slope.

All three potential sites with severe restrictions have Wheelon-Collinston soils (WIE2) with a slope rating of 10 to 30 %. Their limitation rating for slope could be either moderate or severe, based on the site. These are therefore

rated as secondary sites based on slope.

4. Depth to Bedrock

Depth to bedrock information was gathered from the 1974 Soils Survey of Cache Valley (USDA 1974). All fourteen potential sites with moderate restrictions have a depth to bedrock of greater than 60 inches. This is considered a slight restriction when constructing an area method landfill based on the NRCS Soil Interpretations Rating Guide. There are therefore no limitations on these sites and they are all rated as primary sites based on depth to bedrock.

All three potential sites with severe restrictions have a depth to bedrock rating of 24 inches to greater than 60 inches. Their limitation could be either slight, moderate, or severe, depending on the site. Specific on-site studies would be necessary to determine each site's limitation rating for this factor. Therefore, all three of these sites are rated as primary/secondary based on depth to bedrock.

5. Sub-Surface Geology

The Sub-Surface Geology map, Figure 25, was developed from William's map originally produced in 1948 (Williams 1958). This map was digitized into the database using the Calcomp 9500 digitizer with an RMS of 0.019 (61.26 meters). The researcher noted this exceptionally high RMS and tried several times to redigitize the map, but this was the lowest RMS available. The researcher feels

that this is due to the age and scale of the map (1/2 inch = 1 mile). Based on the fact that all potential sites had the same sub-surface geology, this was not considered a major problem for the results of this study. All 17 potential sites have similar sub-surface geology. The geologic sub-structure is composed of rock from the Lake Bonneville Group formation. This formation is made up of very clay-like materials. The researcher spoke with Professor Kaufmann of Utah State University's Geology Department, whose expertise is geomorphology. While the sub-surface geology of the sites is very clay-like, it was stressed that it is not homogeneous and one could therefore expect to find cracks and perched areas which could potentially act as a conduit to underground aquifers. Moreover, any differences between sites with the same Lake Bonneville Group sub-surface geology would be strictly a function of each site's elevation.

The researcher also spoke with Mr. Atkins of Utah DNR Water Rights Department who has significant experience with the local sub-surface geology due to well drillings and boring tests. He said drilling logs in the west side of the valley have found clay depths of over 200 feet with some over 400 feet deep. The conclusion is that all seventeen potential sites have very suitable sub-surface geology and are rated as primary sites based on sub-surface geology.

6. Liquefaction Potential

The Liquefaction Potential Map, Figure 28, was developed from a liquefaction potential map created by Dr. Loren Anderson of Utah State

University's Department of Civil and Environmental Engineering (Anderson et al. 1990). The map was digitized into the database using the Calcomp 9500 digitizer with an RMS of 0.008 (9.716 meters). Liquefaction means that, in the event of a strong enough earthquake, the soil liquefies and can become like quicksand. Any structure built on soils which liquefy can be severely damaged. While there is no specification regarding this factor in either the Utah State or Federal regulations for siting landfills, these regulations do require consideration of unstable areas. Moreover, both state and federal regulations have requirements for seismic impact zones which are based on critical acceleration as is Dr. Anderson's liquefaction potential map. The researcher decided that liquefaction potential would serve as a guide to potentially unstable areas.

Dr. Anderson took factors such as soil type, soil density, soil saturation and boring tests, into consideration in constructing this map. Other geotechnical information from previous investigations was also considered. The rating system developed rates each areas probability of exceeding the critical acceleration in 100 years. Critical acceleration is the amount of ground motion that would be required by an earthquake to cause liquefaction of a soil. The rating system chart, Figure 26, is derived from Dr. Anderson's paper.

In order to check each potential site's liquefaction potential, the researcher used the identity command in ARC. Using first the coverage 'pot03modgt124' as the identity cover with the coverage 'liqp02' as the input

coverage, the new coverage 'liqpotgt124' was created. This coverage showed each of the 14 potential sites with moderate restrictions rating for liquefaction potential. The results are that most sites have either a moderately low, low, or very low liquefaction potential. The preferred sites are those with a liquefaction potential of low or very low. Some sites showed areas of high liquefaction potential, but these areas came out to be less than 5 % of the total acreage of the site. Moreover, these were all small slivers which appeared at the edge of these sites, probably due to closeness to riverbeds where liquefaction potential is high. See Figure 27 for a summary of these findings.

The researcher decided to assign a rating for suitability as a site for an area method sanitary landfill based on the liquefaction potential. Those sites with a liquefaction potential of either very low or low for 90 % or more of their total acreage were considered as primary sites. Those sites with a rating of modlow for 80 % or more of their total acreage were considered as secondary sites. This ranking covers all fourteen potential sites with moderate restrictions.

All three potential sites with severe restrictions have a liquefaction potential of very low and are therefore considered as primary sites. The overall results are fourteen sites ranked as primary and three sites ranked as secondary, based on liquefaction potential.

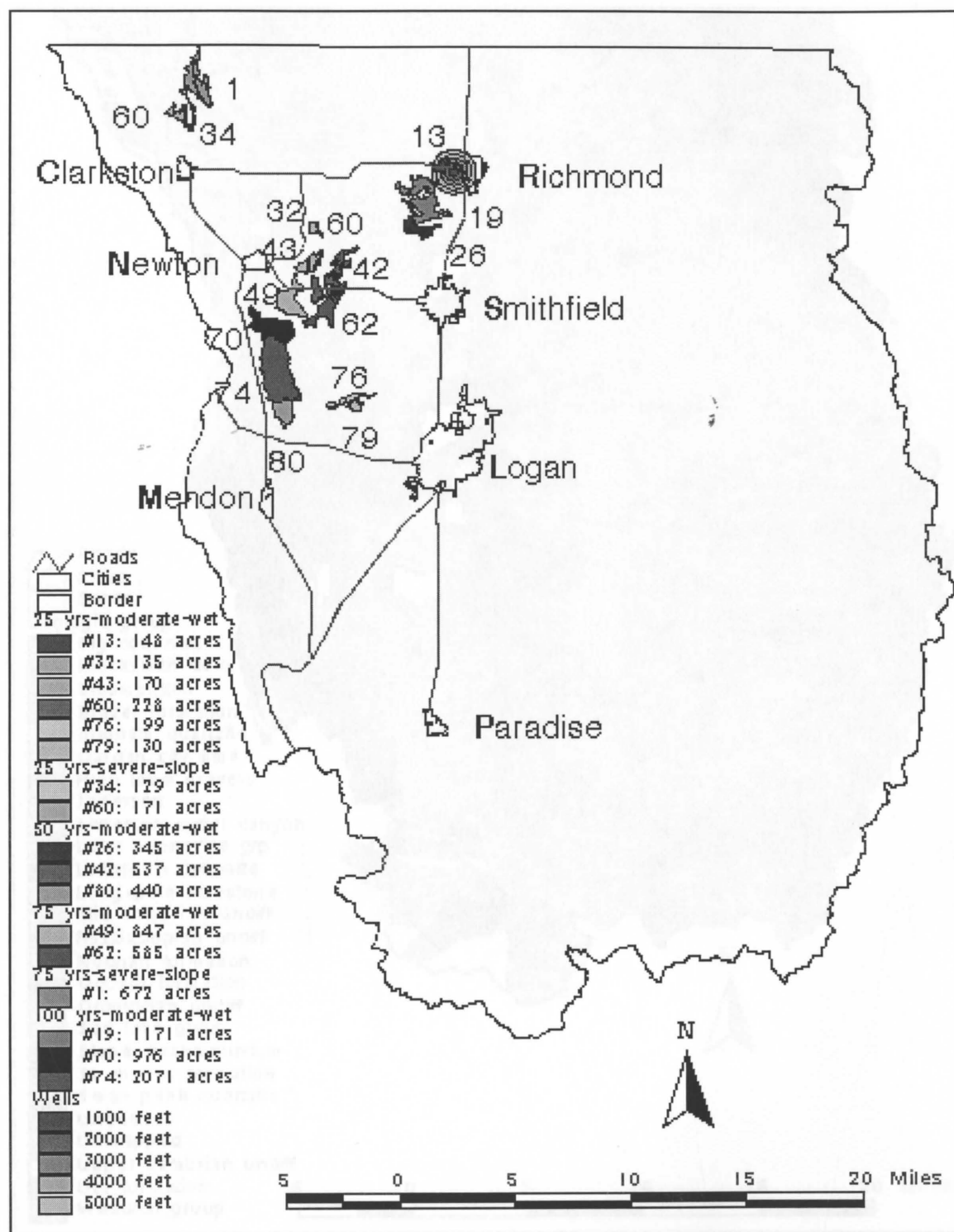


Figure 24. Analysis: Distance from Public Drinking Wells & Springs.

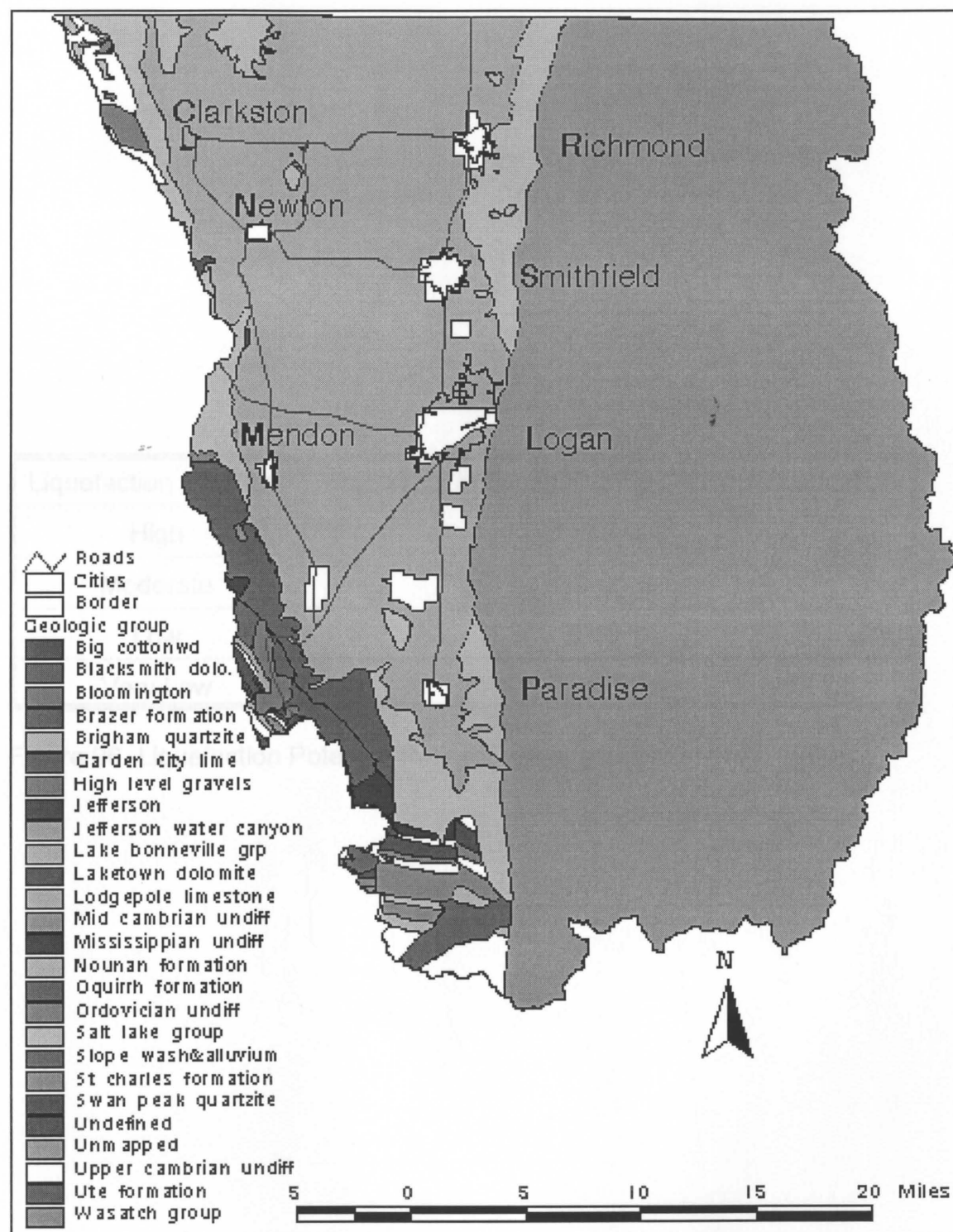


Figure 25. Sub-surface Geology.

Site #	Liquefaction potential (score)	Rating for site use
13 (145 acres)	low (18), moderate (52)	secondary
17 (177 acres)	low (69), moderate (104), moderate (51)	secondary
25 (345 acres)	low (11), moderate (325), high (3)	secondary
32 (136 acres)	low	primary
42 (537 acres)	low	primary
43 (170 acres)	low	primary

Liquefaction Potential	Probability of Exceeding the Critical Acceleration
High	>50 %
Moderate	10-50 %
Low	5-10 %
Very Low	<5 %

Figure 26. Liquefaction Potential Rating System (Anderson et Al. 1990).

50 (440 acres)	low (430), moderate (3)	primary
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Notes: Sites may not be equal due to rounding of sites less than 1 acre

Figure 27. Liquefaction Potential Rating of 14 Potential Sites with Moderate Restrictions

Site #	Liquefaction potential (acres)	Rating for suit. as landfill
13 (148 acres)	low (18), modlow (130)	secondary
19 (1171 acres)	low (69), modlow (1091), modhi (6)	secondary
26 (345 acres)	low (11), modlow (325), hi (8)	secondary
32 (135 acres)	low	primary
42 (537 acres)	low	primary
43 (170 acres)	low	primary
49 (847 acres)	vlow (1), low (792), hi (52)	primary
60 (228 acres)	low	primary
62 (585 acres)	low (578), hi (6)	primary
70 (976 acres)	vlow (262), low (705), hi (6)	primary
74 (2071 acres)	low (2070), hi (1)	primary
76 (199 acres)	low (198), modhi (1)	primary
79 (130 acres)	low	primary
80 (440 acres)	low (436), modhi (3)	primary

(note: totals may not be equal due to rounding of sites less than 1 acre)

Figure 27. Liquefaction Potential Rating of 14 Potential Sites with Moderate Restrictions.

7. Distance to Airport

The Analysis: Distance to Airport map, Figure 29, was created in order to measure the distance from Cache County airport to the potential sites.

According to Utah State Solid Waste Permitting and Management Rule R315-302-1.(2)(a)(v), no new solid waste facility shall be located 10,000 feet of any airport runway end used by turbojet aircraft or within 5,000 feet of any airport runway end used by only piston-type aircraft unless the owner or operator demonstrates that the facility design and operation will not increase the likelihood of bird/aircraft collisions. Additionally, if a new landfill is located within 5 miles of an airport runway end, the owner or operator must notify the effected airport and the Federal Aviation Administration.

The researcher met with Mr. Nilson, Cache County Airport Manager, in order to gather information about the airport. There are presently three runways numbered 17/35, 10/28, and 5/23. Runway 5/23 is presently closed and not in use at all. Runway 17/35 is the largest runway at 5939 feet. According to Mr. Nilson, runway 17/35 will be extended to 8740 feet within the next 10 years. Runway 10/28 is 5015 feet long and no expansion of this runway is planned. Ideally, no new facility would be placed within 5 miles of the runway ends in order to totally eliminate all potential problems, but in reality, this probably will not be possible.

The researcher decided to extend runway 17/35 in the computer and then

draw concentric rings 5,000 feet wide around the airport, out to a distance of 20,000 feet. First, a coverage called 'airport' was created by reselecting out the airport polygon feature from the coverage of built-up areas. Using the buffer command, the airport was buffered by an 1800 foot (549 meters) circle in order to show the distance required to extend runway 17/35. This coverage was called 'airportbuf549'. In ARCEDIT, using coverage 'airportbuf549' as a background coverage, in the airport coverage, runway 17/35 was extended to the circle edge to account for the planned 1800 foot runway extension.

Using the buffer command in ARC, the coverage 'airport' was buffered by 5000 feet, 10,000 feet, 15,000 feet, and 20,000 feet. These coverages were called 'airbuf1524', 'airbuf10k', 'airbuf15k', and 'airbuf20k'. This is approximately 4 miles from the airport, twice the distance necessary to require any remediation for bird collisions. Using the union command in ARC, these four coverages were joined together and the coverage, 'airbuf04', was created. In ARCEDIT, an item called 'distance' was added to this coverage's PAT, and each circle was given its appropriate distance ranking from the airport.

The results are that 3 sites fall within 20,000 feet of the airport. Site 76 is located from between 5,000 to 20,000 feet of runway 5/23, which is a closed runway. Site 79 is located at 10,000 feet from this same runway. Site 62 is located between 15,000 and 20,000 feet of runway 10/28. All other sites are located outside of 20,000 feet from the airport runways.

Based on these results, it is best to give sites 76 and 79 a secondary rating for distance to airport. Even though these potential sites do not presently pose any threat because the runway which would affect them is closed, things could change by the time any new potential site is put into operation. This is especially true considering growth in the area. All other sites are given a rating of primary for this factor.

8. Prevailing Winds

Prevailing wind from a landfill towards a nearby populated area could adversely impact the residents. This section of the study looked at wind data to see if any sites could adversely impact nearby residential areas. Data regarding prevailing winds for 1994 in Cache County were gathered from the Utah Climate Center located at Utah State University. These data are displayed in a wind rose. The wind roses considered in this study are found in Appendix D. The wind rose shows arms which point in a direction from which the wind is blowing. The arm length represents the percentage of time it is blowing from that direction and the arm's width represents the strength with which it is blowing.

There are two wind reading stations in Cache County. One is located southwest of Logan and is called station LOGAN 5SW. The other is located north northwest of Logan near the sewage lagoons around 1400 west and is called station LOGAN 2NNW. The researcher decided to use the wind data from LOGAN 2NNW since it is closer to the potential sites than the other station and

would be more representative of wind data concerning these sites.

According to the Annual Wind Rose, wind blows from the north and north northwest approximately 10 % of the time and from the south and south southeast approximately 8 % of the time. The strongest winds are from 19 to 25 mph from various locations but usually for small percentages of the time. The researcher believed that winds would be most important in the spring and summer when temperatures are warmest. According to the Spring Wind Rose, wind blows from the north northwest approximately 11 % of the time, from the north approximately 10 % of the time, and from the south approximately 9 % of the time. According to the Summer Wind Rose, the wind blows from the north northwest, north, and south approximately 11 % of the time.

The results of this study are that prevailing winds are from mostly the north, north northwest, south, and south southeast. Therefore, areas located to the south, south southeast, north, and north northwest could potentially be susceptible to wind blown odors from a sanitary landfill. The researcher does not know of any scientific data available about how far odors can travel. Based on his own experience growing up on Staten Island, New York, home to the world's largest landfill, he has smelled landfill odors several miles away from the landfill itself. This is probably a function of the size of the open working area and the amount of waste being landfilled.

The researcher therefore decided to give sites a primary rating if they

were located more than 1 mile from residential areas. Additionally, any sites within 1 mile of a residential area and located to the north, northwest, south, or south southeast of a residential area would be given a secondary rating. In ARCEDIT using the distance command, areas were measured from their furthest points to the nearby cities. No sites were found to be within 1 mile of any major residential area. Therefore, all seventeen sites were given a primary rating based on the prevailing winds.

9. Potential Visual Impacts

Any new landfill could have a negative visual impact on its surrounding areas. The researcher discussed visual aspects with Professor Ellsworth of Utah State University's Department of Landscape Architecture (Ellsworth 1995). Professor Ellsworth is an expert on visual analysis in land-use planning. According to Professor Ellsworth, the U.S. Forest Service uses a system to measure visual impacts. The areas of greatest impact are defined as the foreground which is defined as any area within 1/4 to 1/2 mile from the viewpoint. Cache Valley is very wide open with tall mountain ranges running north and south along each side. This expanse has the tendency to minimize any potentially poor views which are located a certain distance from the viewer. Professor Ellsworth suggested that 1/4 mile separation from the viewshed would probably be sufficient to minimize negative visual impacts from a landfill. Moreover, any sites located within 1/4 mile of a viewshed could probably be

successfully buffered visually, perhaps using the expertise of an experienced landscape architect.

The researcher decided to use this rating system as described above. He decided that potential sites that had a majority of their area falling within 1/4 mile of a major viewshed would be given a secondary rating. Any other areas falling outside 1/4 mile from a major viewshed would be given a primary rating. He defined major viewshed areas as Highways 23, 30, 91, and 89/91.

In ARC, the coverage 'pot03modgt124' was buffered by 403 meters (1/4 mile) to create the coverage 'visbuf403'. The same coverage was buffered a second time by 806 meters (1/2 mile) to create the coverage 'visbuf806'. These two coverages were joined using the union command and the new coverage was called 'visbuf01'. An item called 'distance' was added to the PAT and the areas were coded as 1/4 and 1/2 mile distance from the potential site. A similar process was done to buffer the three potential sites with severe restrictions. The final coverage there was called 'slopebuf01'.

The results indicate that Sites 70, 74, and 80 fall between less than 1/4 to greater than 1/2 mile from highway 23 at certain points along this road. Additionally, Site 19 falls just about 1/2 mile from Highway 91. Due to the possibility of visually buffering sites and based on the size of the sites along Highway 23, the researcher decided that they would still be rated as primary since the majority of the sites are outside 1/4 mile from Highway 23. All other

sites are located greater than 1/4 mile from these major viewsheds as well.

Therefore, all seventeen potential sites are given a primary rating based on the visual impacts factor. See Figure 30 for this map.

10. Distance From Waste Centroid

Distance from the waste centroid is a factor to consider since this will impact the costs of waste transportation. The researcher decided to use the downtown Logan, 200 North and Main street, as the waste centroid.

Sites 70, 74, 76, 79, and 80 are located between 8 and 13 miles from the centroid. Sites 13, 19, and 26 are located approximately 12 miles from the centroid. Sites 32, 42, 43, 49, 60, and 62 are located approximately 13 miles from the centroid. Sites 1, 34, and 60, above Clarkston, are located approximately 23 miles from the centroid. These figures were transferred into the final rating table, as shown in Figures 31 and 32.



Figure 28: Equidistance Potential

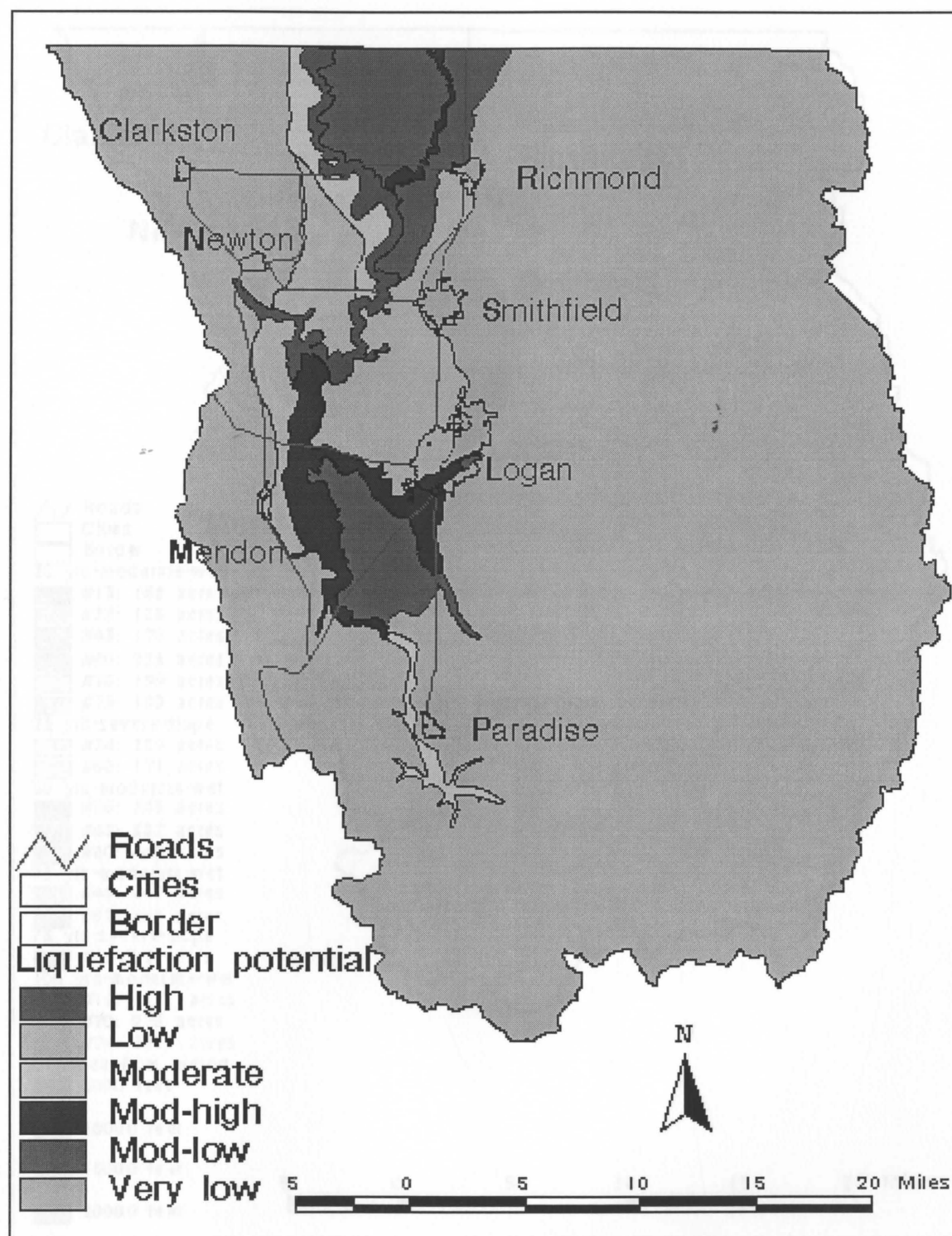


Figure 28. Liquefaction Potential. *Alpert*

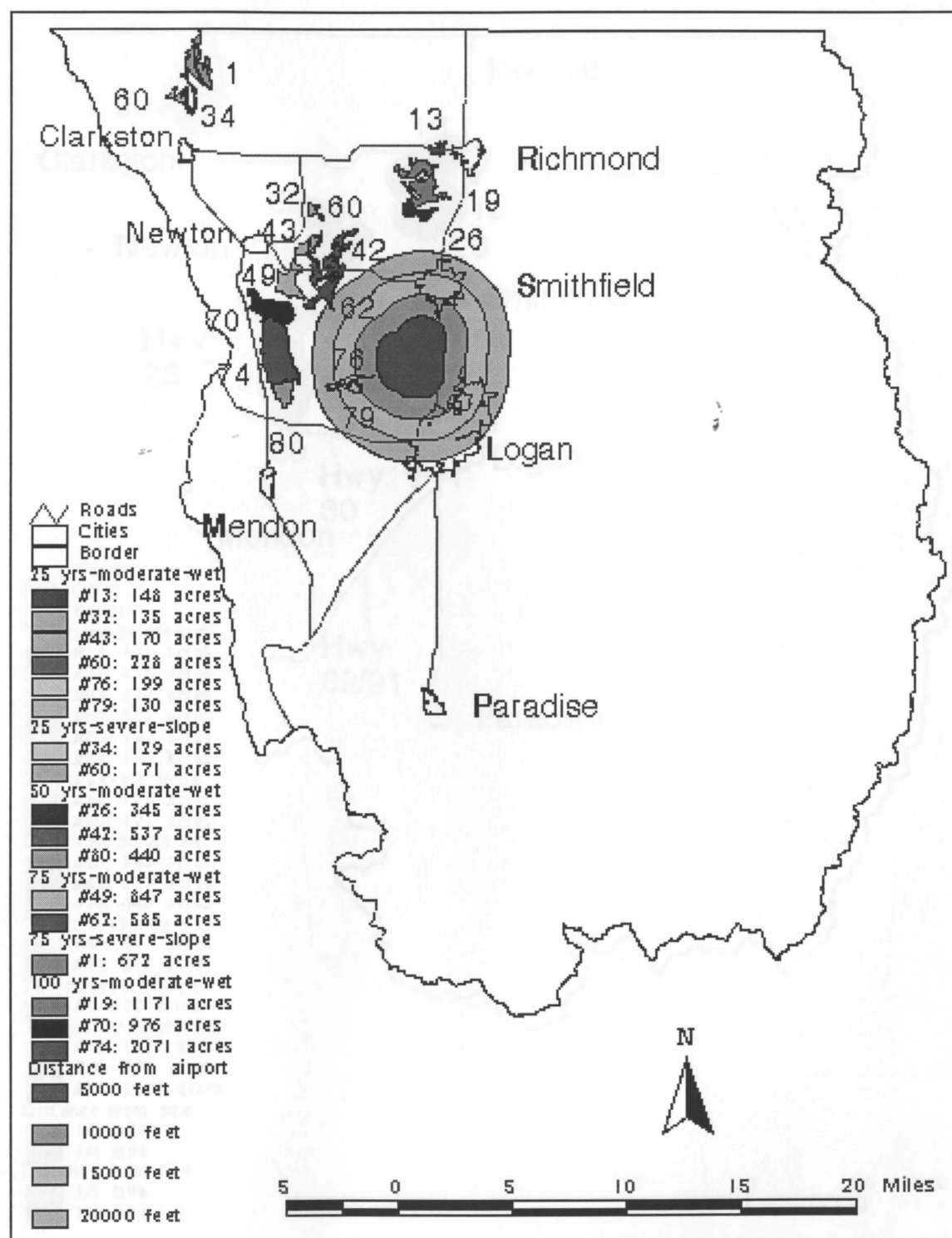


Figure 29. Analysis: Distance from Airport.

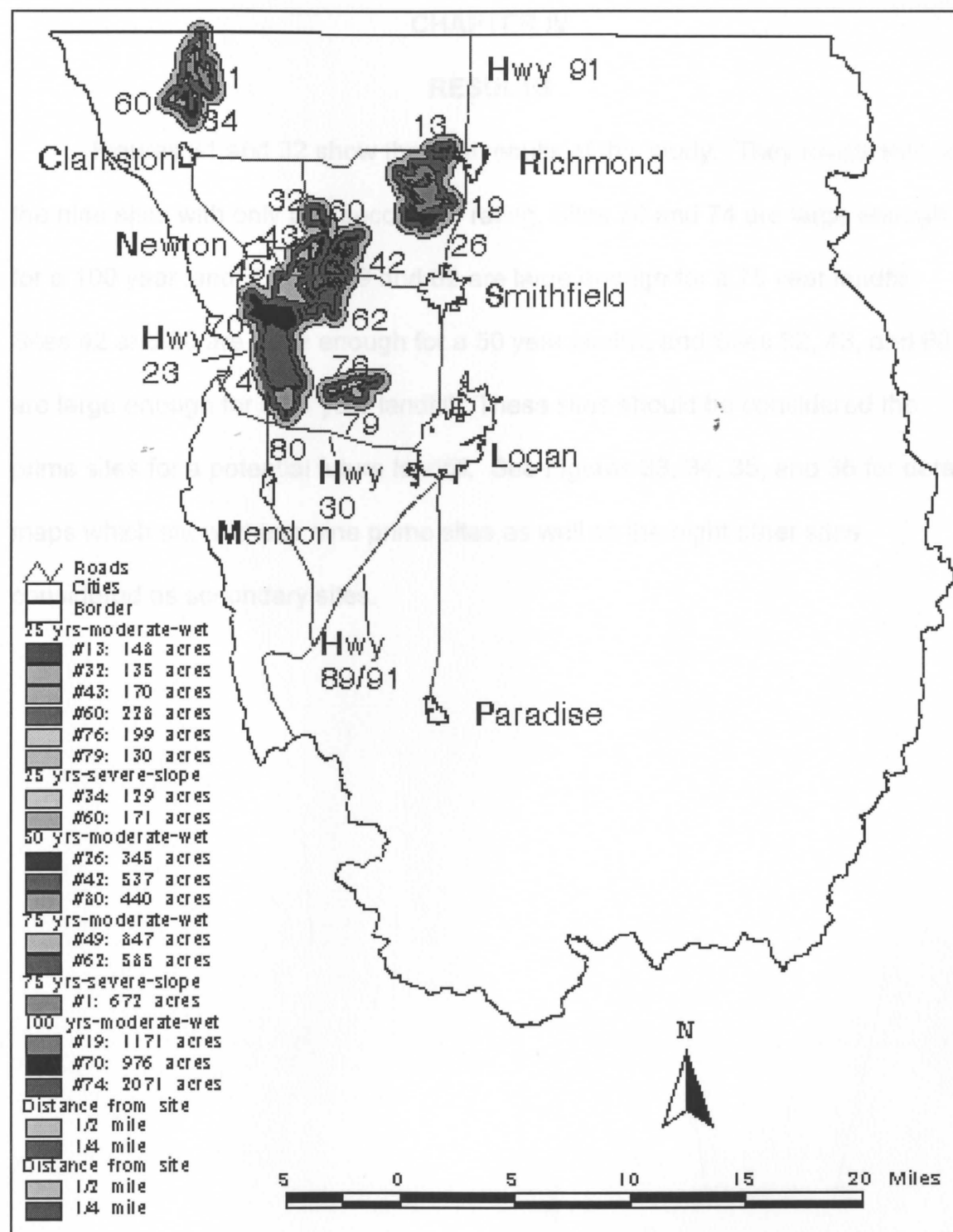


Figure 30. Analysis: Visual Distance to/from Sites.

CHAPTER IV

RESULTS

Figures 31 and 32 show the final results of this study. They reveal that of the nine sites with only one secondary rating, Sites 70 and 74 are large enough for a 100 year landfill, Sites 49 and 62 are large enough for a 75 year landfill, Sites 42 and 80 are large enough for a 50 year landfill, and Sites 32, 43, and 60 are large enough for a 25 year landfill. These sites should be considered the prime sites for a potential future landfill. See Figures 33, 34, 35, and 36 for detail maps which show these nine prime sites as well as the eight other sites considered as secondary sites.

Moderate sites-75 years											
42	847	s	p	p	p	p	p	p	p	p	13
62	580	s	p	p	p	p	p	p	p	p	13
Large sites-100 years											
70	1471	s	p	s	p	p	s	p	p	p	12
74	676	s	p	p	p	p	p	p	p	p	13
74	2071	s	p	p	p	p	p	p	p	p	13

Notes: p = primary, s = secondary, size depth to water table, size depth to bedrock, size of waste mounds, dist = distance to waste control

Figure P1. Final Rating Table of 14 Potential Sites with Moderate Restrictions

Site #	Acres	dtw	well	slope	dtb	geol	liq-pot	air-port	wind	vis .	dist.
Moderate sites-25 years											
13	148	s	s	s	p	p	s	p	p	p	13
32	135	s	p	p	p	p	p	p	p	p	13
43	170	s	p	p	p	p	p	p	p	p	13
60	228	s	p	p	p	p	p	p	p	p	13
76	199	s	p	p	p	p	p	s	p	p	8:13
79	130	s	p	p	p	p	p	s	p	p	8:13
Moderate sites-50 years											
26	345	s	p	s	p	p	s	p	p	p	12
42	537	s	p	p	p	p	p	p	p	p	13
80	440	s	p	p	p	p	p	p	p	p	8:13
Moderate sites-75 years											
49	847	s	p	p	p	p	p	p	p	p	13
62	585	s	p	p	p	p	p	p	p	p	13
Moderate sites-100 years											
19	1171	s	p	s	p	p	s	p	p	p	12
70	976	s	p	p	p	p	p	p	p	p	8:13
74	2071	s	p	p	p	p	p	p	p	p	8:13

Notes: p= primary, s= secondary, dtw=depth to water table, dtb=depth to bedrock, vis.= visual impacts, dist.= distance to waste centroid

Figure 31. Final Rating Table of 14 Potential Sites with Moderate Restrictions.

Site #	Acre	dtw	well	slope	dtb	geol	liq-pot	air-port	wind	vis.	dist.
Severe sites-25 years											
34	129	p	p	s	p/s	p	p	p	p	p	23
60	171	p	p	s	p/s	p	p	p	p	p	23
Severe sites-75 years											
1	672	p	p	s	p/s	p	p	p	p	p	23

Notes: p= primary, s= secondary, dtw=depth to water table, dtb=depth to bedrock, vis.= visual impacts, dist.= distance to waste centroid

Figure 32. Final Rating Table of 3 Potential Sites with Severe Restrictions.

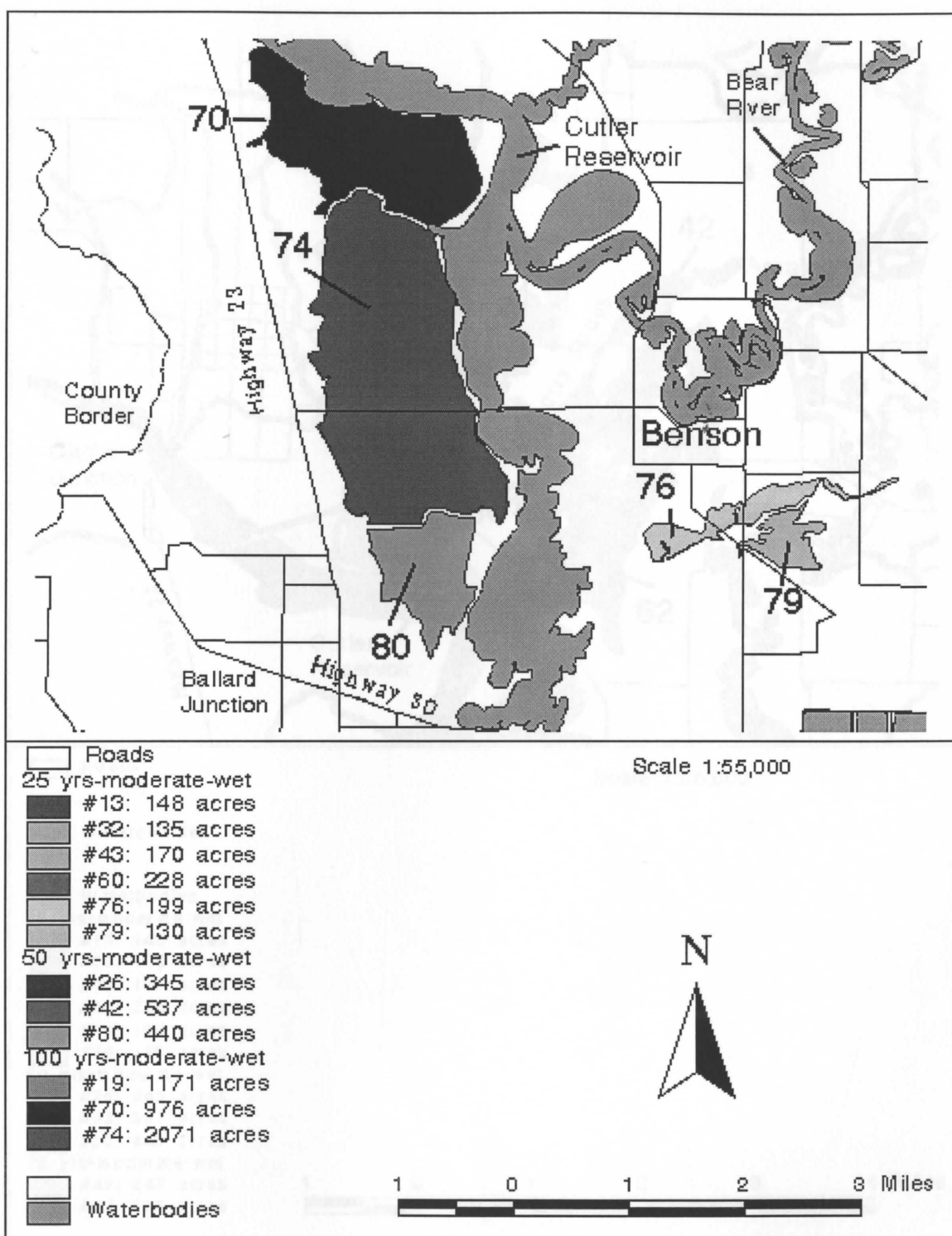


Figure 33. Potential Sites: 70, 74, 76, 79, & 80.

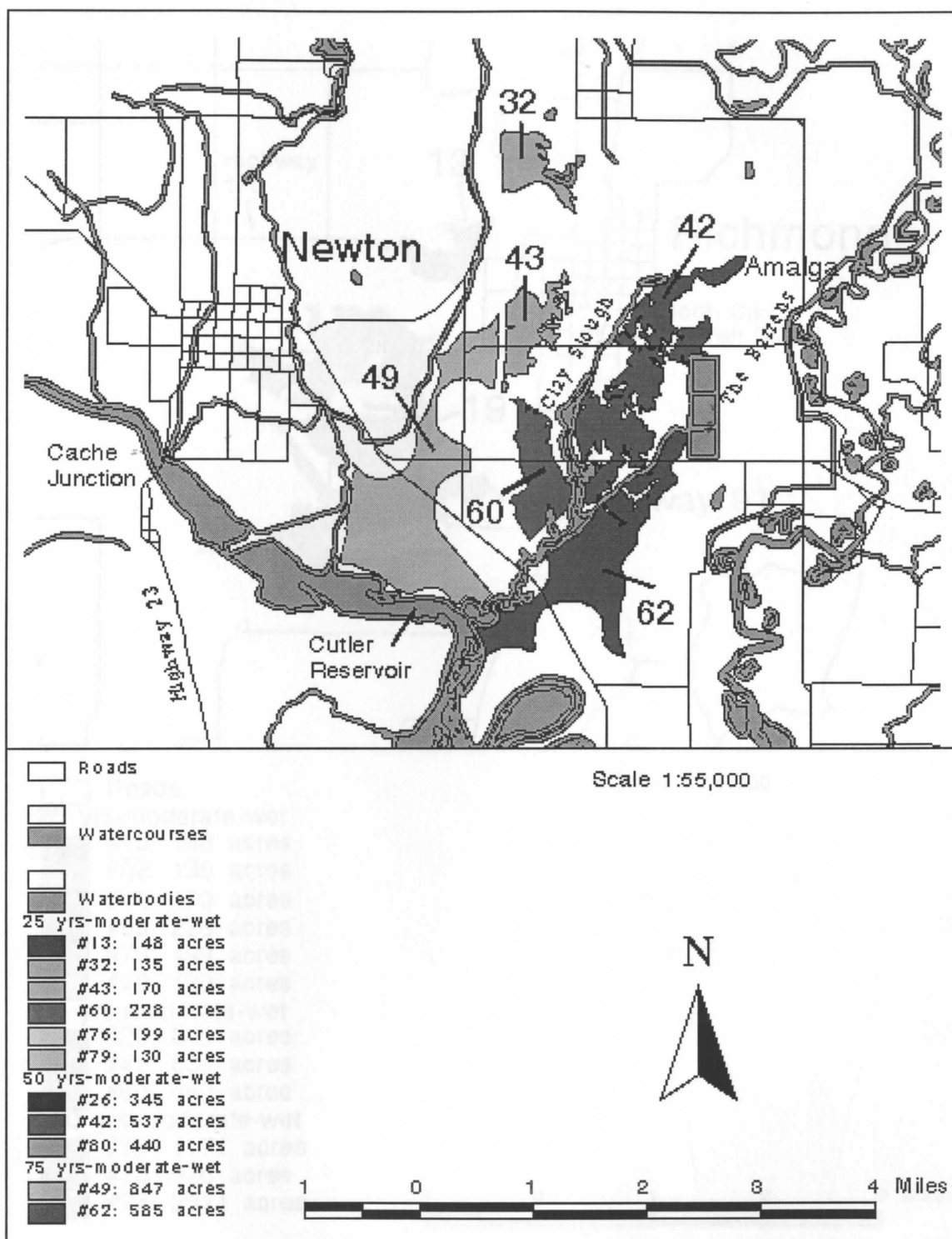


Figure 34. Potential Sites: 32, 42, 43, 49, 60, & 62.

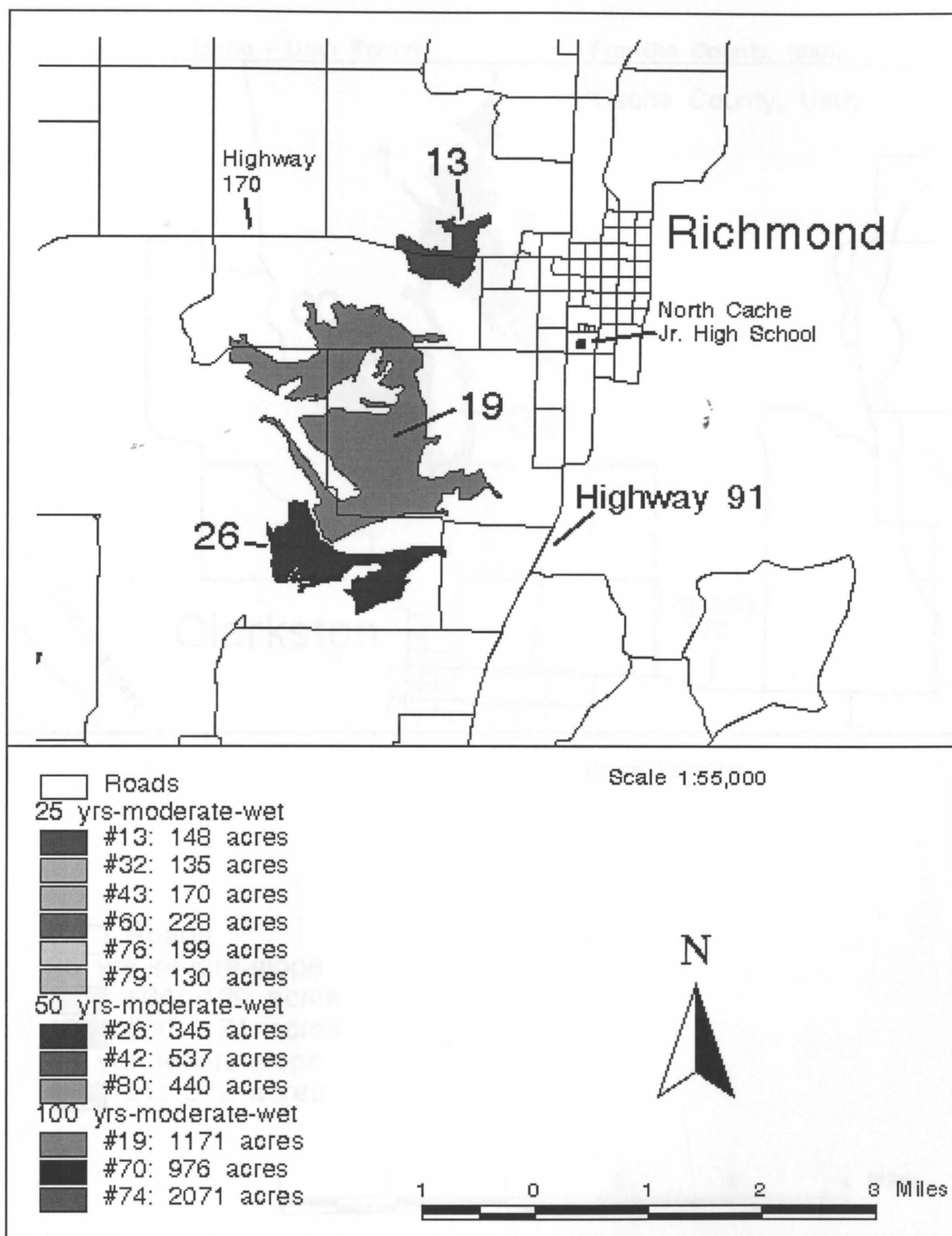


Figure 35. Potential Sites: 13, 19, & 26.

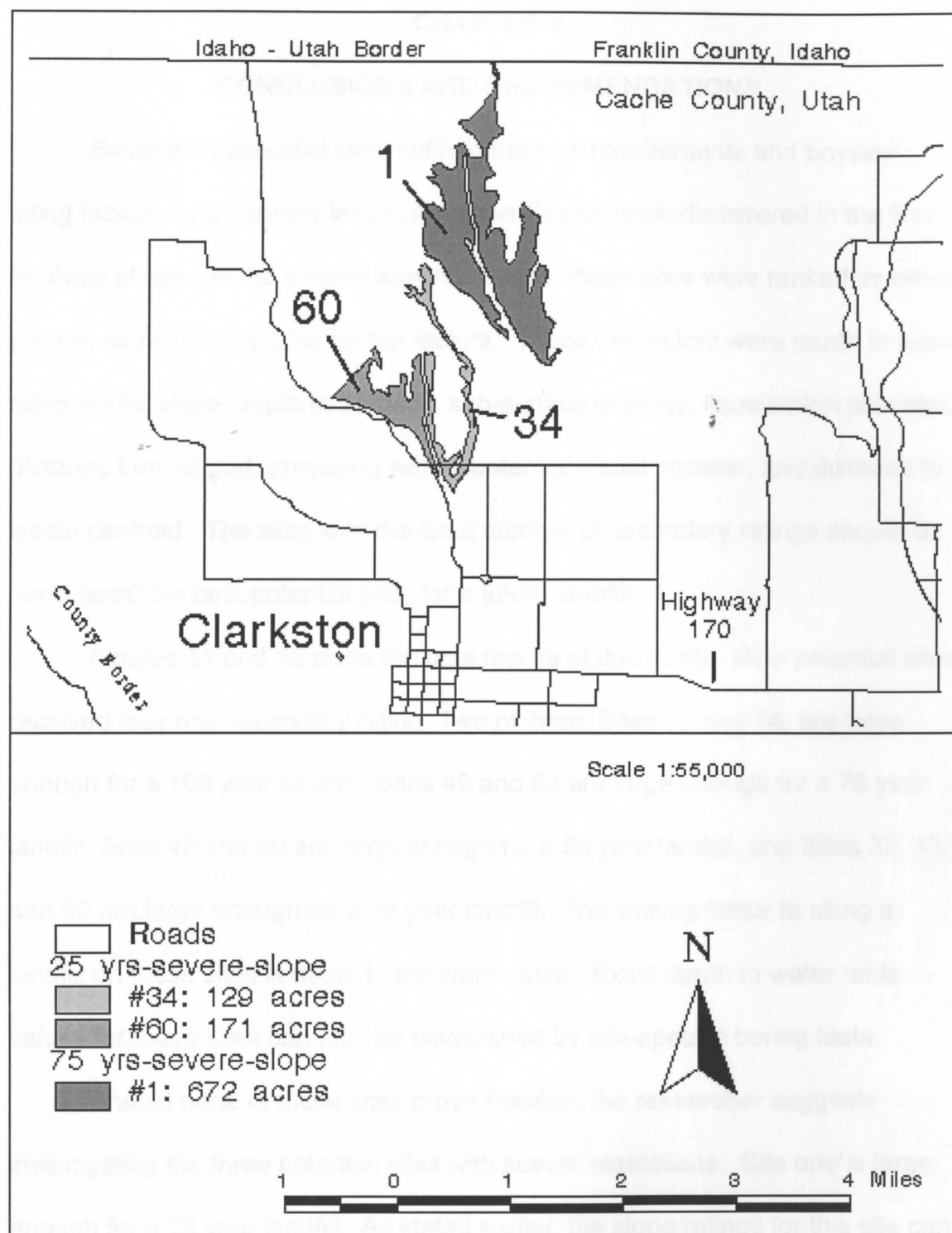


Figure 36. Potential Sites: 1, 34, & 60.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Seventeen potential sites fulfilling the size requirements and physical siting factors for a sanitary landfill in Cache County were discovered in the first analysis phase. In the second analysis phase, these sites were ranked as either primary or secondary sites for ten factors. These ten factors were depth to water table, wells, slope, depth to bedrock, sub-surface geology, liquefaction potential, distance from airport, prevailing winds, potential visual impacts, and distance to waste centroid. The sites with the least number of secondary ratings should be considered the best potential sites for a future landfill.

Figures 31 and 32 show the final results of this study. Nine potential sites received only one secondary rating. Two of them, Sites 70 and 74, are large enough for a 100 year landfill. Sites 49 and 62 are large enough for a 75 year landfill, Sites 42 and 80 are large enough for a 50 year landfill, and Sites 32, 43, and 60 are large enough for a 25 year landfill. The limiting factor to siting a landfill on these sites is depth to the water table. Exact depth to water table values for these sites can only be established by site-specific boring tests.

Should none of these sites prove feasible, the researcher suggests investigating the three potential sites with severe restrictions. Site one is large enough for a 75 year landfill. As stated earlier, the slope ratings for this site can range from 10 to 30 %. The researcher checked the 7.5 minute quadrangle map

for Clarkston and there are indeed areas with 10 % or less slope. Since these areas have no problem with depth to water table, they might be viable sites.

There are three other limiting factors; depth to bedrock, distance from waste centroid, and peripheral impacts on Idaho. The depth to bedrock may be greater than 60 inches depending on the site. This could be tested in on-site investigations.

Transportation costs would necessarily be higher because these sites are approximately 23 miles from the waste centroid, about twice the distance of other sites. One possible solution to reduce transportation costs would be a transfer station, perhaps located at the existing landfill in Logan. A transfer station is an intermediary facility where waste is stored before final transportation by large trucks to a landfill. Costs would still be higher, but the number of trips to the potential sites would at least decrease.

One must also consider the effects on Idaho. These three sites are located very near the Utah/Idaho border. This study only looked at all the factors considered for Cache County. It might be necessary to examine the impacts of these sites on Idaho, should these sites be chosen for further study.

The researcher would like to again point out that the scope of this project was to analyze Cache County for potential sites for a Municipal Solid Waste Landfill (MSWLF). The regulations for siting a MSWLF are very stringent in order to protect the environment and the public from potential health hazards. The

seventeen potential sites meet these regulations. These seventeen sites, and potentially many more discovered in the preliminary phase of this project, could possibly be used as a landfill for other types of waste, such as construction and demolition debris. The chance of groundwater pollution by leachate is significantly less from these other types of waste, therefore, the regulations governing such landfills are less stringent. This would require further research outside the parameters of this study.

Future use of this study must recognize that the data scale used requires further site-specific investigation to verify accuracy. Some of the more important data to be investigated are depth to water table, soils, and visual impacts. Perhaps the most important item which will determine whether a site is successfully chosen and brought into service is the issue of visual impacts.

The public will likely have a negative reaction to siting a landfill near their community, no matter how deep the water table or how good the soil type. Their visceral reaction will be that they do not want to see a landfill. It has a negative connotation, producing images of scavenging birds, rats, and repulsive odors. Whether one can actually see the landfill from his or her home will greatly influence its acceptability. The researcher used a very basic distance-to-viewshed analysis for this study. He recommends future studies do a visibility analysis to exactly determine which of these recommended sites are visible from selected key view points. He further recommends that a public visibility

preference analysis be done to propose different shaped landfills in these difference sites. These different styles of landfills could be produced using visual simulation programs currently available. Additionally, the expertise and resources of the USU Department of Landscape Architecture and Environmental Planning should be tapped to assist with this project.

Another issue requiring further research is land ownership which was not considered as a factor in this study. Although these potential sites show promise as landfill sites, the land owners must be amenable to selling the land to the county. The researcher believes that there should be enough of a variety of sizes and locations available to permit successful siting of a new sanitary landfill to serve future generations of Cache County residents.

One big issue of concern throughout this study was recycling and the impact of recycling rates on the solid waste generation rates. The public could be shown the impacts of different recycling scenarios on their landfill using a GIS. A GIS could be used to show that a certain recycling rate would extend the life of their landfill a certain number of years. Moreover, with a certain recycling rate, a 40 foot high landfill would last 50 years, for example, but with a higher recycling rate, the same height would last 60 years. The average cost savings per year could be factored in to demonstrate to the public the cost-effectiveness of a sound recycling plan.

Other counties using this study as a resource for siting their own solid

waste facility should note the following hurdles which were overcome to produce the final results. The largest hurdle was data availability and collection. There is presently no one source of county-specific GIS data in Utah. The Automated Geo Reference Center (AGRC) has some county-specific data, but much of it is at a state-wide scale, clipped out for counties. The researcher had to network with a multitude of agencies to get required data, and the scale and accuracy varied greatly. Working on several different computers was also problematic, causing many computer-related problems such as loss of data and transfer problems when compressing files. The solutions to these problems would be to have one centralized data office which has all the county-specific data required at a county-wide scale (approximately 1:100,000 or less). The researcher recommends having one computer which has a GIS as well as text editing and spreadsheet programs.

Finally, the researcher would like to comment on the suitability of various software programs used to complete this project. ARC/INFO was used to construct the data base. Included in ARC/INFO were ARCEDIT and ARCPLOT. These systems are commonplace now in many city government offices. Logan City Public Engineering is fully equipped with these software programs. These programs have positive and negative aspects. One positive aspect is that they allow quick analysis of complicated data. These data can be manipulated to show different scenarios, and this can also be done rather quickly. All the data is

geographically referenced, therefore it is smart data which knows where it is located geographically. This permits accurate spatial analysis that may not be possible with a database which is not geographically referenced.

There are a number of negative aspects of these programs however. They are still fairly user unfriendly. They require knowledge of the designated entries and there are many reference manuals with a great deal of user information to be absorbed. They have a long learning curve and usually require the beginning user to ask many questions of a more experienced user. These negative aspects are perhaps understandable in a system which can perform such complicated transactions as ARC/INFO. Additionally, ARC/INFO is expensive.

The researcher used ARCVIEW to produce the maps for this project. This is a much easier system to learn since it is based on the windows concept. It is a fairly intuitive, point and click program. The researcher had a two day course in Salt Lake City and was able to comfortably use ARCVIEW after this course. ARCVIEW can manipulate data for display, but cannot do the complicated manipulations and creation of data which are possible in ARC/INFO. The latest version of ARCVIEW is affordable, costing approximately \$900.

The researcher recommends that the Department of Environmental Health and Solid Waste should at least get ARCVIEW software loaded into their computer system. That will permit them to use the data gathered in this project.

He further recommends that if it is possible to get another license from the Department of Public Engineering for ARC/INFO for a reasonable price, this should also be pursued. This would permit the department to store and analyze all data required for future phases of the landfill siting project.

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APPENDICES

APPENDIX A. SOLID WASTE PERMITTING AND MANAGEMENT RULE

APPENDICES

UTAH ADMINISTRATIVE CODE

R313-302-1

Utah Department of Environmental Quality, 1999

R315-302-1. **Subject-matter Quality.** The subject-matter quality of the R315-302-1. Rules for Facility Operation, including General Facility Operating Standards, and General Requirements, R315-302-1.1, General Standards for Design and Construction.

(1) **Subject-matter Quality.** These standards apply to each new, existing facility and any existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation.

These standards apply to a facility that has been constructed before July 1, 1995.

- (1) **Subject-matter Quality.** These standards apply to each new, existing facility and any existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation.
- (2) **Subject-matter Quality.** These standards apply to each new, existing facility and any existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation.
- (3) **Subject-matter Quality.** These standards apply to each new, existing facility and any existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation.
- (4) **Subject-matter Quality.** These standards apply to each new, existing facility and any existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation.
- (5) **Subject-matter Quality.** These standards apply to each new, existing facility and any existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation, and to each new, existing facility that is seeking facility operation.

APPENDIX A. SOLID WASTE PERMITTING AND MANAGEMENT RULE

UTAH ADMINISTRATIVE CODE

R315-302-1

(Utah Department of Environmental Quality, 1995)

R315. Environmental Quality, Solid and Hazardous Waste. R315-302. Solid Waste Facility Location Standards, General Facility Requirements, and Closure Requirements. R315-302-1. Location Standards for Disposal Facilities.

(1) Applicability. These standards apply to each new disposal facility and any existing disposal facility seeking facility expansion, including landfills, landtreatment disposal sites, and piles that are to be closed as landfills. These standards, unless otherwise noted, do not apply to:

- (a) an existing facility or a facility that has engaged in closure before July 15, 1993;
- (b) transfer stations and drop box facilities;
- (c) piles used for storage;
- (d) composting or utilization of sludge or other solid waste on land;
- (e) class IV landfills;
- (f) hazardous waste disposal sites regulated by Rules R315-50 and Rule R315-101; or
- (g) industrial solid waste facilities.
- (2) Location Standards. Each applicable solid waste facility shall be subject to the following location standards:
 - (a) Land Use Compatibility. No facility shall be located within:
 - (i) one thousand feet of a national, state or county park, monument, or recreation area; designated wilderness or wilderness study area; or wild and scenic river area;
 - (ii) ecologically and scientifically significant natural areas, including wildlife management areas and habitat for threatened or endangered species as designated pursuant to the Endangered Species Act of 1982;
 - (iii) farmland classified or evaluated as "prime," "unique," or of "statewide importance" by the U.S. Department of Agriculture Soil Conservation Service under the Prime Farmland Protection Act;
 - (iv) one-fourth mile of-
 - (A) existing permanent dwellings, residential areas, and other incompatible structures such as schools or churches unless otherwise allowed by local zoning or ordinance; and
 - (B) historic structures or properties listed or eligible to be listed in the State or National Register of Historic Places;
 - (v) ten thousand feet of any airport

runway end used by turbojet aircraft or within 5,000 feet of any airport runway end used by only piston-type aircraft unless the owner or operator demonstrates that the facility design and operation will not increase the likelihood of bird/aircraft collisions. Every new and existing disposal facility is subject to this requirement. If a new landfill or a lateral expansion of an existing landfill is located within five miles of an airport runway end, the owner or operator must notify the effected airport and the Federal Aviation Administration;

- (vi) areas with respect to archeological sites that would violate Section 9-8-404; or
- (vii) an area that is at variance with any locally-adopted land use plan or zoning requirement unless otherwise provided by local law or ordinance.

(b) Geology. No new facility or lateral expansion of an existing facility shall be located in a subsidence area, a dam failure flood area, an underground mine, a salt dome, a salt bed, or on or adjacent to geologic features which could compromise the structural integrity of the facility.

(i) Fault Areas. A new facility or a lateral expansions of an existing facility shall not be located within 200 feet of a Holocene fault unless the owner or operator demonstrates to the Executive Secretary that an alternative setback distance of less than 200 feet will prevent damage to the structural integrity of the unit and will be protective of human health and the environment

(ii) Seismic Impact Zones. A new facility or a lateral expansion of an existing facility shall not be located in seismic impact zones unless the owner or operator demonstrates to the satisfaction of the Executive Secretary that all containment structures, including liners, leachate collection systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site.

(iii) Unstable Areas. The owner or operator of an existing facility, a lateral expansion of an existing facility, or a new facility located in an unstable area must demonstrate to the satisfaction of the Executive Secretary that engineering measures have been incorporated into the facility design to ensure that the integrity of the structural components of the facility will not be disrupted. The owner or operator must consider the following factors when determining whether an area is unstable:

- (A) on-site or local soil conditions that may result in significant differential settling;

(B) on-site or local geologic or geomorphologic features; and

(C) on-site or local human-made features or events, both surface and subsurface.

(c) Surface Water.

(i) No new facility or lateral expansion of an existing facility shall be located on any public land that is being used by a public water system for water shed control for municipal drinking water purposes, or in a location that could cause contamination to a lake, reservoir, or pond.

(ii) Floodplains. No new or existing facility shall be located in a floodplain unless the owner or operator demonstrates to the Executive Secretary that the unit will not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in a washout of solid waste so as to pose a hazard to human health or the environment.

(d) Wetlands. No new facility or lateral expansion of an existing facility shall be located in wetlands unless the owner or operator demonstrates to the Executive Secretary that:

(i) where applicable under section 404 of the Clean Water Act or applicable state wetlands laws, the presumption that a practicable alternative to the proposed landfill is available which does not involve wetlands is clearly rebutted;

(ii) the unit will not violate any applicable state water quality standard or section 307 of the Clean Water Act;

(iii) the unit will not jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of a critical habitat protected under the Endangered Species Act of 1973;

(iv) the unit will not cause or contribute to significant

degradation of wetlands. The owner or operator must demonstrate the integrity of the unit and its ability to protect ecological resources by addressing the following factors:

(A) erosion, stability, and migration potential of native wetland soils, muds, and deposits used to support the unit;

(B) erosion, stability, and migration potential of dredged and fill materials used to support the unit;

(C) the volume and chemical nature of the waste managed in the unit;

(D) impacts on fish, wildlife, and other aquatic resources and their habitat from release of the solid waste;

(E) the potential effects of catastrophic release of waste to the wetland and the resulting impacts on the environment; and (F) any additional factors, as necessary, to demonstrate that ecological resources in the wetland are sufficiently protected;

(v) to the extent required under section 404 of the Clean Water Act or applicable state wetlands laws, steps have been taken to attempt to achieve no net loss of wetlands, as defined by acreage and function, by first avoiding impacts to wetlands to the maximum extent practicable, as required by Subsection R315-302-1(2)(d)(i), then minimizing unavoidable impacts to the maximum extent practicable, and finally offsetting remaining unavoidable wetland impacts through all appropriate and practicable compensatory mitigation actions (e.g., restoration of existing degraded wetlands or creation of man-made wetlands);

and

(vi) sufficient information is available to make a reasonable determination with respect to these demonstrations.

(e) Ground Water.

(i) No new facility shall be located at a site:

(A) where the bottom of the lowest liner is less than five

feet above the historical high level of ground water; or (B) for a landfill that is not required to install a liner, the lowest level of waste must be at least ten feet above the historical high level of ground water.

(C) If the aquifer beneath a landfill contains ground water which has a Total Dissolved Solids (TDS) of 10,000 mg/l or greater and the landfill is constructed with a composite liner, the bottom of the lowest liner may be less than five feet above the historical high level of the ground water.

(ii) No new facility shall be located over a sole source aquifer as designated in 40 CFR 149.

(iii) No new facility shall be located over groundwater classed as EB under Section R317-6-3.3.

(iv) Unless all units of the proposed facility are constructed with a composite liner or other equivalent design approved by the Executive Secretary:

(A) a new facility located above any aquifer containing ground water which has a TDS content below 1,000 mg/l which does not exceed applicable ground water quality standards for any

contaminant is permitted only where the depth to ground water is greater than 100 feet; or

(B) a new facility located above any aquifer containing ground water which has a TDS content between 1,000 and 3,000 mg/l and does not exceed applicable ground water quality standards for any contaminant is permitted only where the depth to ground water is 50 feet or greater.

- (C) The applicant for the proposed facility will make the

demonstration of ground water quality necessary to determine the appropriate aquifer classification.

(v) No new facility shall be located in designated drinking water source protection areas or, if no source protection area is designated, within a distance to existing drinking water wells or springs for public water supplies of 250 days ground water travel time. This requirement does not include on-site operation wells. The applicant for the proposed facility will make the demonstration, acceptable to the Executive Secretary, of hydraulic conductivity and other information necessary to determine the 250 days ground water travel distance.

(vi) Ground Water Exception. Subject to the ground water performance standard stated in Subsection R315-303-3(l), if a solid waste disposal facility is to be located over an area where the ground water has a TDS of 10,000 mg/l or greater, or where there is an extreme depth to ground water, or where there is a natural impermeable barrier above the ground water, or where there is no ground water, the Executive Secretary may exempt the disposal site, on a case by case basis, from some design criteria and ground water monitoring. Exemption of ground water monitoring may require the owner or operator to make the demonstration stated in Subsection R315-308-1(3).

(3) Existing Facility Exception. Any existing facility not meeting the location standards pertaining to airports, Subsection R315-302-1(2)(a)(v); pertaining to floodplains, Subsection R315302-1(2)(c)(i); or pertaining to unstable areas, Subsection R315302-1(2)(b)(iii), must close by October 9, 1996 and conduct post-closure activities in accordance with the closure and post-closure requirements of Section R315-302-3 and Subsection R315-3034(4). The Executive Secretary may approve an extension of up to two years if:

- (a) there is no available alternative disposal capacity; and
- (b) there is no immediate threat to human health or

the environment.

(4) Exemptions. Exemptions from the location standards with respect to airports, floodplains, wetlands, fault areas, seismic impact zones, and unstable areas cannot be granted. Exemptions from other location standards of this section may be granted by the Executive Secretary on a site specific basis if it is determined that the exemption will cause no adverse impacts to public health or the environment.

(a) No exemption may be granted without application to the Executive Secretary.

(b) If an exemption is granted, a facility may be required to have more stringent design, construction, monitoring program, or operational practice to protect human health or the environment.

(c) All applications for exemptions shall meet the conditions of Section R315-311-3 pertaining to public notice and comment period.

Item Number	Item Description	Regulation Reference
1. Foundation	Foundation shall be constructed of concrete or masonry and shall be designed to support the structure and its contents. The foundation shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified
2. Wall	Walls shall be constructed of concrete or masonry and shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified
3. Floor	Floors shall be constructed of concrete or masonry and shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified
4. Surface	Surfaces shall be constructed of concrete or masonry and shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified
APPENDIX B. DESIRED DATA TABLE OF STATE AND FEDERAL REGULATIONS		
5. Roof	Roofs shall be constructed of concrete or masonry and shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified
6. Wall	Walls shall be constructed of concrete or masonry and shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified
7. Ceiling	Ceilings shall be constructed of concrete or masonry and shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified
8. Substructure	Substructures shall be constructed of concrete or masonry and shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified
9. Foundation	Foundations shall be constructed of concrete or masonry and shall be designed to resist lateral forces and shall be constructed to prevent water infiltration.	not specified

<u>Data Desired</u>	<u>State Regulations</u> <u>(R315-302-1)</u>	<u>Federal Regulation</u> <u>40 CFR Parts 257 & 258</u>
1. Groundwater	<ul style="list-style-type: none"> - not above an aquifer (see exceptions in appendix (2)(e)(ii),(iii), (iv) - not within a designated drinking water source protection area. If none designated, not within distance of 250 days ground water travel time of drinking water wells or springs for public water supplies (2)(e)(v) - ground water exemptions based on certain criteria (see appendix (2)(e)(vi)) 	not specified
2. Well water	see "1. Groundwater" above	not specified
3. Water table	<u>landfill with liner</u> : not less than 5 feet above historical high level of groundwater <u>landfill without liner</u> : not less than 10 feet above historical high level of groundwater <u>composite liner</u> : less than 5 feet above historical high level of groundwater if TDS of water is 10,000 mg/l or greater (2)(e)(i)(A) through (C)	not specified
4. Surface water	not on any public land used by a public water system for water shed control for municipal drinking water purposes, or in a location that could cause contamination to a lake, reservoir, or pond (2)(c)(i)	not specified
5. Soils	not specified (see Unstable areas)	not specified
6. Slope	not specified (see Unstable areas)	not specified
7. Depth to bedrock	not specified	not specified
8. Sub-surface geology	not in a subsidence area, a dam failure flood area, an underground mine, a salt dome, a salt bed, or on or adjacent to geologic features which could compromise the structural integrity of the facility (2)(b)	not specified
9. Zoning/planning	not within an area that is at variance with any locally-adopted land use plan or zoning requirement unless otherwise provided by local law or ordinance (2)(a)(vii)	not specified

<u>Data Desired</u>	<u>State Regulations</u> <u>(R315-302-1)</u>	<u>Federal Regulation</u> <u>40 CFR Parts 257 & 258</u>
10. General location and separation requirements i.e. from parks, homes, institutional structures, historic areas etc.	<u>not within:</u> - farmland classified as prime, unique, or of statewide importance by USDA SCS under Prime Farmland Preservation Act (2)(a)(iii) - areas with respect to archeological sites that would violate Section 9-8-404 (2)(a)(vi) - <u>1,000 ft</u> from a national, state or county park, monument or recreation area; designated wilderness or wilderness study area; or wild and scenic river area (2)(a)(i) - <u>1/4 mile from:</u> - existing permanent dwellings, residential areas and other incompatible structures such as schools or churches, unless otherwise allowed by local zoning or ordinance; and - historic structures or properties listed or eligible to be listed in the State or National Register of Historic Places (2)(a)(iv)(a) & (b)	not specified
11. Climate	not specified	must not violate any applicable requirements of State Implementation Plan pursuant to section 110 of Clean Air Act (refers to mainly open burning) (\$258.24)
12. Environmentally sensitive areas (i.e. wetlands, critical habitat, t & e species)	- <u>not within:</u> - ecologically and scientifically significant areas i.e. wildlife mgt area, habitat for t&e species (2)(a)(ii) - wetlands (2)(d) (See exceptions in appendix (2)(d)(i) through (vi))	similar to state regulation
13. Unstable areas	must guarantee integrity of facility with engineering measures. Factors to be considered in determining instability are soil conditions resulting in differential setting, geologic or geo- morphologic features, human-made features or events, surface and subsurface (2)(b)(iii)	similar to state regulation
14. Seismic impact zones	not within a seismic impact zone (see appendix for exception) (2)(b)(ii)	similar to state regulation
15. Fault zones	not within 200 feet of a Holocene fault (see appendix for exception) (2)(b)(i)	similar to state regulation

<u>Data Desired</u>	<u>State Regulations</u> <u>(R315-302-1)</u>	<u>Federal Regulation</u> <u>40 CFR Parts 257 & 258</u>
16. Airports	<ul style="list-style-type: none"> - <u>10,000 ft</u>: from any airport runway end used by turbojet type aircraft - <u>5,000 ft</u>: if airport served by only piston-type aircraft. - unless can demonstrate that facility will not increase the likelihood of aircraft/bird collisions. - <u>5 miles</u>: must advise airport and FAA. (2)(a)(v)	similar to state regulation
17. Floodplains	not within a floodplain unless demonstrated will not restrict flow of 100 year flood, reduce temporary water storage capacity of floodplain, or result in waste washout (2)(c)(ii)	similar to state regulation
18. Visual buffers	not specified	not specified
19. Access	not specified	not specified
20. Miscellaneous	see various exceptions and exemptions in appendix (3) & (4)	not specified

APPENDIX 2. SOILS INFORMATION ABOUT POTENTIAL SITES

<u>Soilsy</u> ¹	<u>name</u>	<u>dtw</u>	<u>dtb</u>	<u>texture</u> ²	<u>slope</u>	<u>lfrest</u>	<u>restitem</u>
AhA	Airport	0-40	>60	silo	0-3	severe	wetness
Ak	Airport	0-40	>60	sicllo	0-3	severe	wetness
Am	Airport-Salt Lake	0-40	>60	silo,sicl	<1	severe	wetness
ArA	Avon	>60	>60	sicllo	0-3	slight	
ArB	Avon	>60	>60	sicllo	3-6	slight	
ArC	Avon	>60	>60	sicllo	6-10	mod	slope
ArD	Avon	>60	>60	sicllo	10-20	severe	slope
AsC	Avon-Collinstn	>60	>60	sicllo,lo	6-10	mod	slope
AsE	Avon-Collinstn	>60	>60	sicllo,lo	10-30	severe	slope
BAF	Barfuss-Leatham	>60	>60	silo,sicllo	30-50	severe	slope
BcA	Battle Creek	>60	>60	sicllo	0-2	slight	
BmB	Blackrock	>60	>60	gvlo	3-6	slight	
BmC	Blackrock	>60	>60	gvlo	6-10	mod	slope
Ca	Cache	0-20	>60	sicl	0-1	severe	wetness
Cd	Cardon	30 (40-60)	>60	sicl	0-3	severe	wetness
Ck	Collett	20-36 (40-60)	>60	sicllo	0-3	mod	wetness
CmC	Collinston	>60	>60	lo	1-6	slight	
CmD	Collinston	>60	>60	lo	6-10	mod	slope
CmE2	Collinston	>60	>60	lo	10-30	severe	slope
CoA	Crookston	>60	>60	lo	0-3	slight	
CoC	Crookston	>60	>60	lo	3-6	slight	
GrA	Green Canyon	>60	>60	gvlo	0-3	severe	seepage
GsA	Greenson	30-40 (40-60)	>60	lo	0-3	severe	wetness

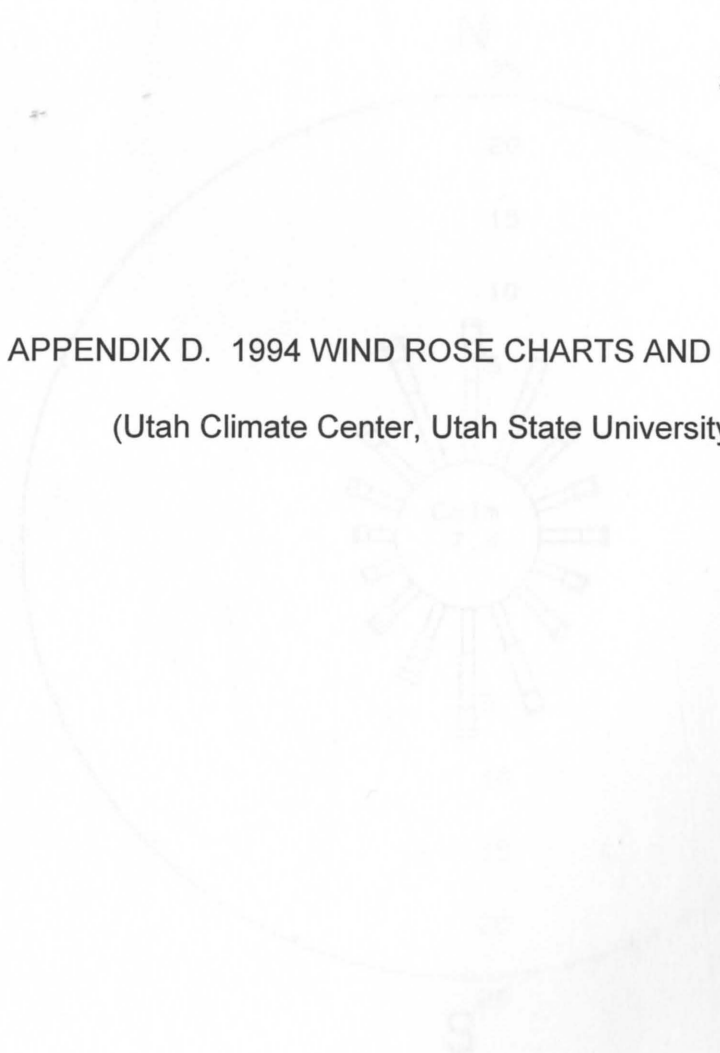
<u>Soilsy</u> ¹	<u>name</u>	<u>dtw</u>	<u>dtb</u>	<u>texture</u> ²	<u>slope</u>	<u>lfrest</u>	<u>restitem</u>
GsB	Greenson	30-40 (40-60)	>60	lo	3-6	severe	wetness
GsC	Greenson	30-40 (40-60)	>60	lo	6-10	severe	wetness
GuA	Greenson	30-40 (40-60)	>60	gvlo	0-1	severe	wetness
HfE	Hiibner	>60	>60	stcllo	1-30	severe	slope
HgE2	Hillfield	>60	>60	silos	20-30	severe	slope
HuC	Hyrum	>60	>60	gvlo	4-8	slight	
HuE	Hyrum	>60	>60	gvlo	10-25	severe	slope
HyC	Hyrum	>60	>60	colos	4-8	slight	
Jo	Jordan	30-48	>60	siclos	1-3	severe	wetness
Jr	Jordan-Lasil	30-48	>60	siclos	0-1	severe	wetness
KfA	Kidman	40-60+	>60	fisdlos	0-2	mod	wetness
Ks	Kirkham-Shay	30-50	>60	silos, siclos	0-1	severe	flood, wet
Kt	Kirkham-Shay	30-50	>60	silos, siclos	0-1	severe	flood, wet
Ln	Lewiston	10-30 (30-40)	>60	fisdlos	0-3	severe	wetness
Lo	Lewiston	10-30 (30-40)	>60	fisdlos	0-3	severe	wetness
Lr	Logan	0-40 (40-60)	>60	siclos	0-3	severe	wetness
McB	McMurdie	>60	>60	silos	3-6	slight	
MdE2	McMurdie-Hillfield	>60	>60	silos	10-30	severe	slope
MeA	Mendon	>60	>60	silos	0-3	slight	
MeB	Mendon	>60	>60	silos	3-6	slight	
MeC	Mendon	>60	>60	silos	6-10	mod	slope
MfB	Mendon-Collinston	>60	>60	silos, lo	1-6	slight	

<u>Soilsy</u> ¹	<u>name</u>	<u>dtw</u>	<u>dtb</u>	<u>texture</u> ²	<u>slope</u>	<u>lfrest</u>	<u>restitem</u>
MfE2	Mendon-Collinston	>60	>60	silo,lo	6-30	mod-severe	slope
MoG2	Munk-Blkrock	>60	20-40	gvlo	30-70	severe	slope,dtb
NcA	Nibley	30-40 (50-60)	>60	siclo	0-3	severe	wetness
NcB	Nibley	30-40 (50-60)	>60	siclo	3-6	severe	wetness
Pn	Payson	30-50	>60	silo	0-1	severe	flood,wet
pond	pond water						
Pu	Provo	26-36 (50-60)	>60	gvlo	0-1	severe	seepage, wetness
Pv	Provo	26-36 (50-60)	>60	gvlo	0-3	severe	seepage, wetness
Qu	Quinney	30-50	>60	silo	0-1	severe	wetness
RfG2	Richmond-Nebeker	>60	10-20	vystlo,silo ,colo	30-70	severe	slope,dtb, seepage
RhB	Ricks	>60	>60	gvlo	3-6	severe	seepage
RhC	Ricks	>60	>60	gvlo	6-10	severe	seepage
river	river water						
Rs	Roshe Springs	0-36 (30-60)	>60	silo	0-3	severe	wetness
Rt	Rough broken land	no valid info					
Sd	Salt Lake	0-30 (30-60)	>60	siclo	1-3	severe	flooding wetness
Se	Salt Lake	0-30 (30-60)	>60	sicl	<1	severe	flooding wetness
Sf	Salt Lake-Logan	0-30 (30-60)	>60	siclo	<1	severe	flooding wetness
Sg	Salt Lake-Roshe Springs	0-30 (30-60)	>60	sicl,silo	0-1	severe	flooding wetness

<u>Soilsy</u> ¹	<u>name</u>	<u>dtw</u>	<u>dtb</u>	<u>texture</u> ²	<u>slope</u>	<u>lfrest</u>	<u>restitem</u>
SvA	Steed	>60	>60	gvlo	0-3	severe	seepage
SwF2	Sterling	>60	>60	gvlo	20-50	severe	seep,slope
TmA	Timpanogos	36-54 (>60)	>60	silos	0-3	slight	
TnA	Timpanogos	36-54 (>60)	>60	silos	0-3	severe	wetness
TrA	Trenton	40-60 (20-40)	>60	siclos	0-2	mod	wetness
TrB	Trenton	40-60 (20-40)	>60	siclos	2-4	mod	wetness
TrC	Trenton	40-60 (20-40)	>60	siclos	4-8	mod	wetness
TrD2	Trenton	40-60 (20-40)	>60	siclos	8-20	mod	wetness slope
TtA	Trenton	40-60 (20-40)	>60	siclos	0-2	severe	wetness
undef	undefined						
w	water						
WhE	Wheelon	>60	24->60	silos	10-30	severe	slope
WhF2	Wheelon	>60	24->60	silos	30-50	severe	slope
WIE2	Wheelon-Collinston	>60	24->60	silos,lo	10-30	severe	slope
Wn	Winn	30-50	>60	silos	0-3	severe	wetness
Wp	Winn-Provo	30-50	>60	silos,lo	0-3	severe	seep,wet
Wr	Woods Cross	10-30	>60	siclos	0-3	severe	wetness

Note 1: Soilsy=soil symbol, name = soil name, dtw = depth to water table, dtb = depth to bedrock, texture = soil texture, slope = percent of slope, lfrest = landfill restriction rating, restitem = restriction type for soil

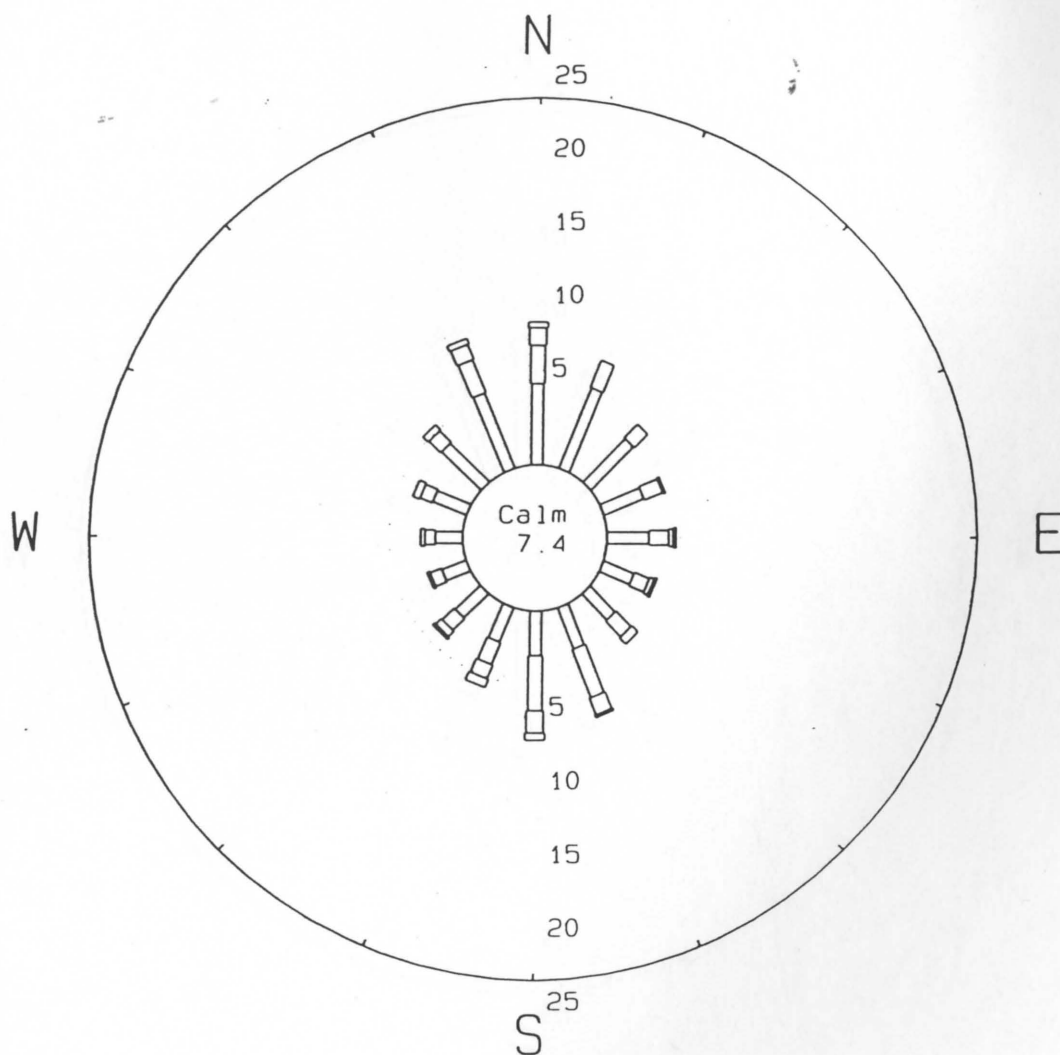
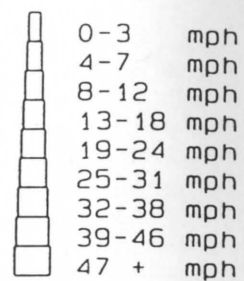
Note 2: Texture codes: cl = clay, co=cobbles, fi=fine, gv = gravelly, lo = loam, sd=sandy, si = silty, st=stoney, vy=very



(Utah Climate Center, Utah State University, 1995)

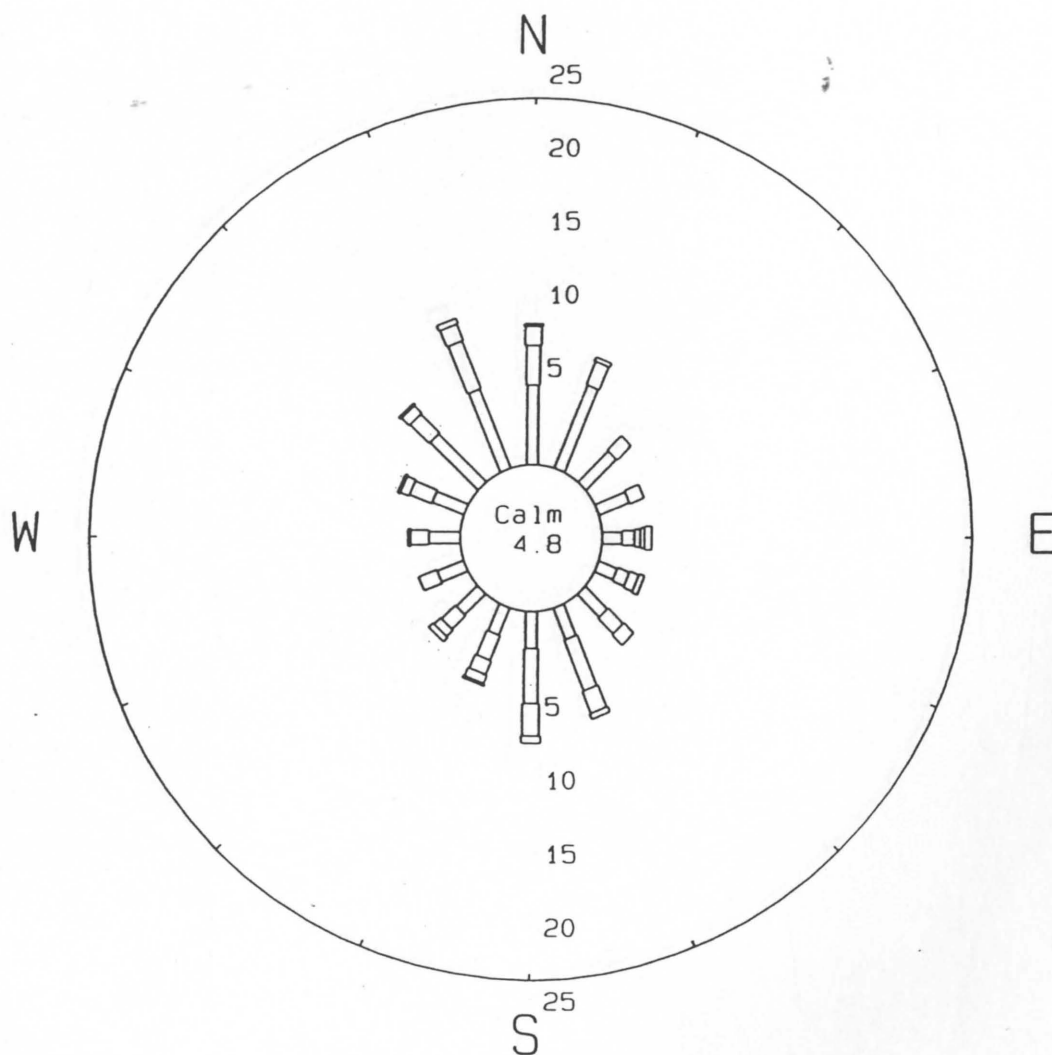
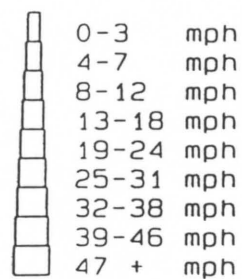
WIND ROSE

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Location : LOGAN 2NNW (CSI)
Interval : Annual (Jan-Dec) 1994
Latitude : 41 45 N
Longitude : 111 52 W
Elevation : 4450 FEET
Station :
Sum_Period: 1994
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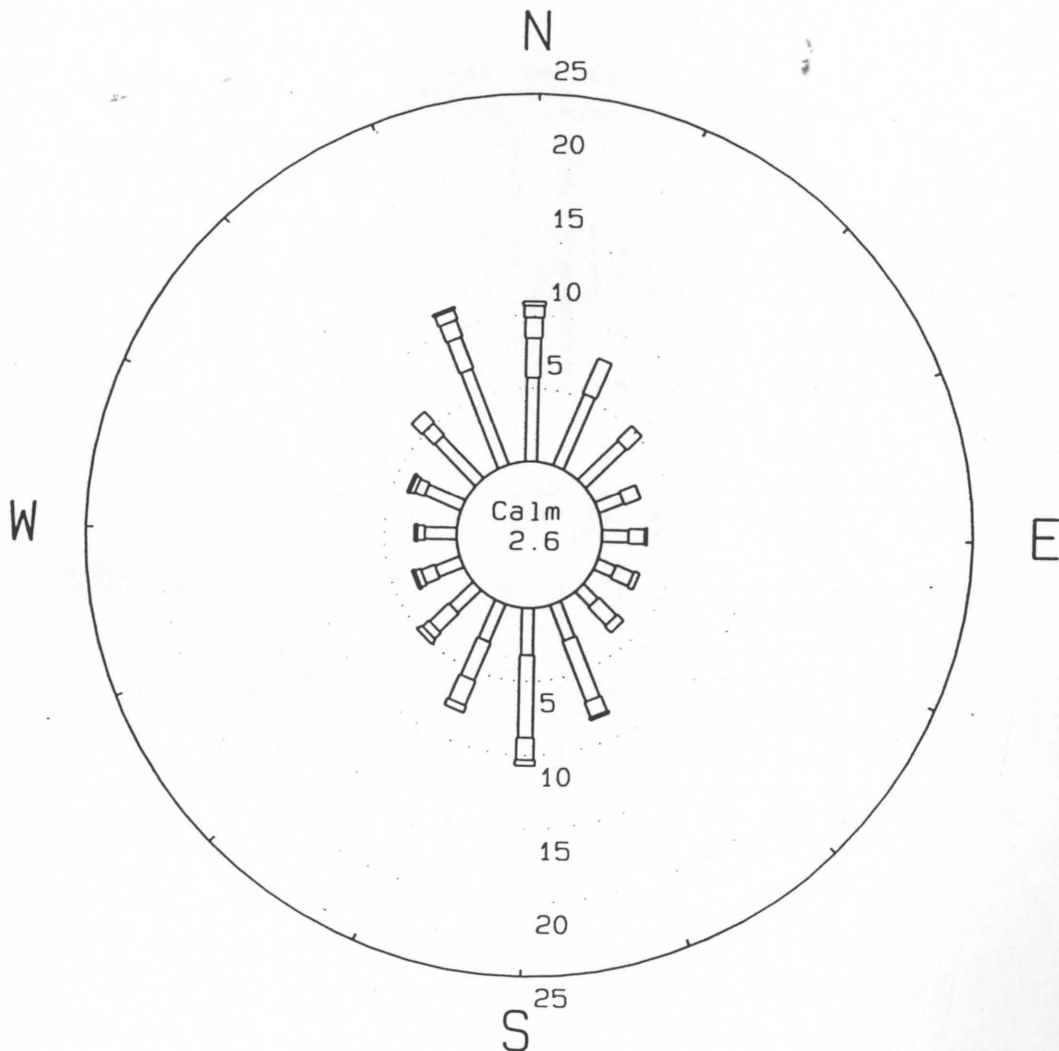
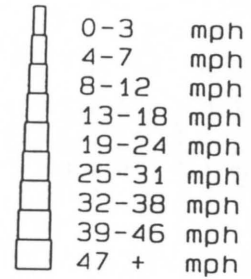
WIND ROSE

Location : LOGAN 2NNW (CSI)
Interval : Spring Season (Mar-May) 1994
Latitude : 41 45 N
Longitude : 111 52 W
Elevation : 4450 FEET
Station :
Sum_Period: 1994



WIND ROSE

Location : LOGAN 2NNW (CSI)
Interval : Summer Season (Jun-Aug) 1994
Latitude : 41 45 N
Longitude : 111 52 W
Elevation : 4450 FEET
Station :
Sum_Period: 1994



LOGAN 2NNW (CSI)
Annual (Jan-Dec) 1994
Midnight to Midnight

WINDROSE HISTOGRAM	N	N E	N E	E N	E	E S	S E	S S	S	S W	W S	W	W S	W	W N	N W	N N
1.3 - 4	5.5	5.9	4.2	3.0	2.9	2.3	2.5	3.0	3.0	2.5	2.3	1.7	1.8	2.4	3.7	5.5	
4 - 8	2.6	2.0	1.3	1.3	1.3	1.1	1.5	3.5	3.7	1.6	1.1	0.8	0.7	0.9	1.1	2.4	
8 - 13	1.2	0.1	0.0	0.2	0.3	0.3	0.6	1.2	1.5	1.0	0.5	0.2	0.3	0.5	0.5	1.1	
13 - 19	0.4	0.0	0.0	0	0.2	0.2	0.1	0.2	0.5	0.6	0.2	0.1	0.1	0.1	0.1	0.4	
19 - 25	0.1	0	0	0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0	0.0	0	0	0.1	
25 - 32	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0	0	0	0	
32 - 39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
39 - 47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
> 47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Calm 7

LOGAN 2NNW (CSI)
Summer Season (Jun-Aug) 1994
Midnight to Midnight

WINDROSE HISTOGRAM	N	N E	N E	E N	E	E S	S E	S S	S	S W	W S	W	W S	W	W N	N W	N N
1.3 - 4	5.7	5.3	3.8	1.8	1.8	1.3	1.4	2.6	3.2	2.8	2.2	1.8	2.2	2.7	4.0	7.0	
4 - 8	2.7	2.6	1.4	1.2	1.1	1.3	1.7	4.4	5.6	2.8	1.8	1.0	0.5	0.7	1.1	2.3	
8 - 13	1.4	0.0	0.1	0.0	0.2	0.4	0.6	1.1	1.5	1.8	0.6	0.4	0.2	0.3	1.0	1.2	
13 - 19	0.8	0.0	0.0	0	0.1	0.1	0.1	0.2	0.4	0.5	0.4	0.2	0.0	0.2	0.0	0.7	
19 - 25	0.3	0	0	0	0	0	0.0	0	0	0.1	0	0	0	0	0	0.2	
25 - 32	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
32 - 39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
39 - 47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
> 47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Calm 3

LOGAN 2NNW (CSI)
Spring Season (Mar-May) 1994
Midnight to Midnight

WINDROSE HISTOGRAM	N	N E	N E	E N	E	E S	S E	S S	S	S W	W S	W	W S	W	W N	N W	N N
1.3 - 4	5.4	6.1	3.0	2.3	1.4	1.4	2.2	2.3	2.5	2.0	2.0	1.9	2.1	2.3	4.6	5.8	
4 - 8	2.7	1.7	1.4	1.1	0.9	0.9	1.5	3.7	3.7	1.8	1.3	1.3	1.2	1.6	1.8	3.5	
8 - 13	1.3	0.3	0.1	0.1	0.4	0.7	1.0	1.6	2.2	1.0	0.6	0.1	0.2	0.6	0.7	1.2	
13 - 19	0.2	0.1	0	0	0.3	0.4	0.0	0.4	0.5	0.6	0.4	0.1	0.1	0.2	0.2	0.4	
19 - 25	0.1	0	0	0	0.5	0.0	0.0	0.1	0.1	0.2	0	0	0.0	0	0	0.0	
25 - 32	0	0	0	0	0.0	0	0	0	0	0.1	0	0	0	0	0	0	
32 - 39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
39 - 47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
> 47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Calm 5